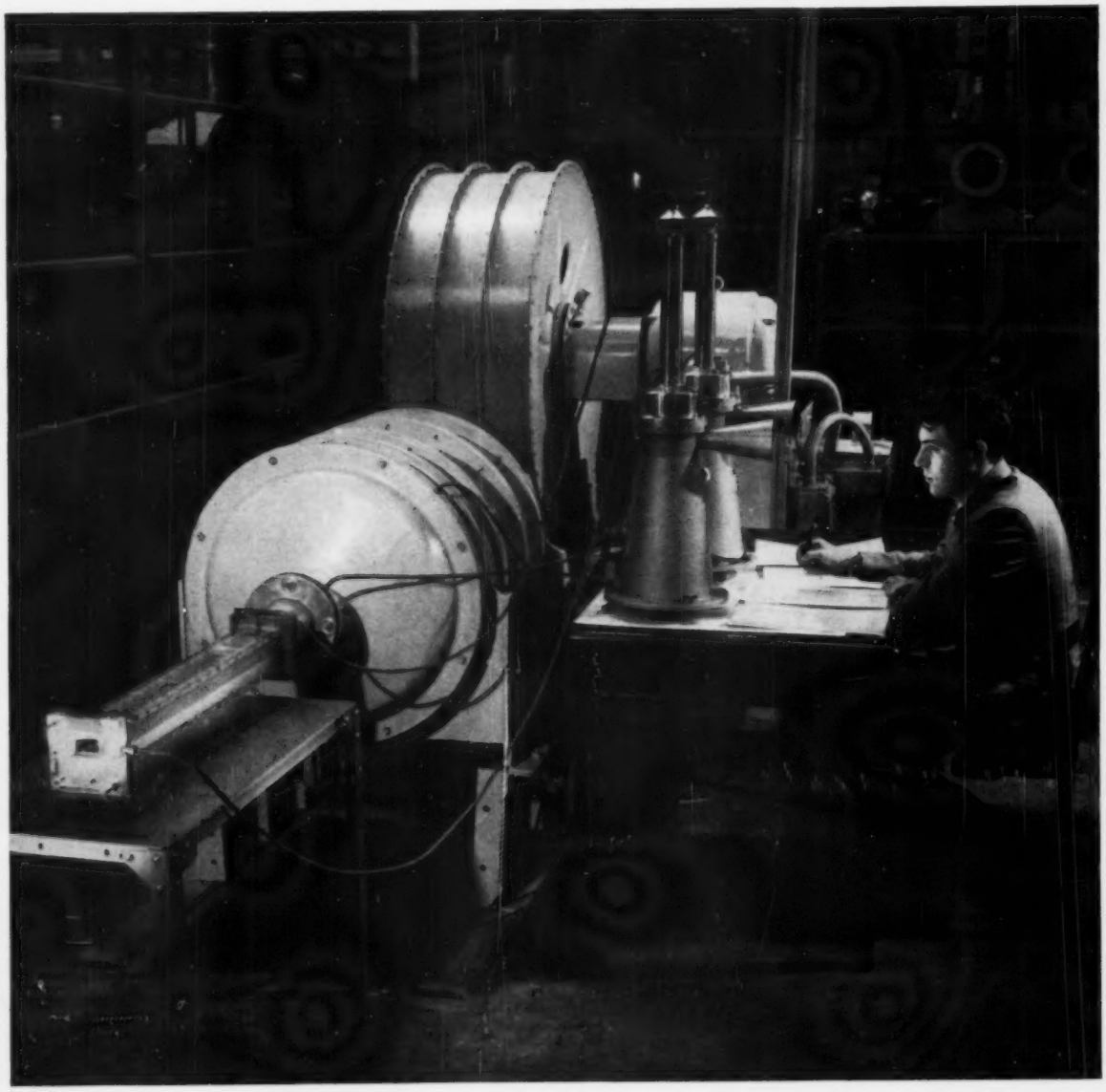
THE BEAMA JOURNAL

NOVEMBER 1958



Measuring the pressure drop across a nuclear fuel element

A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

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Editorial

Telling the World

The achievements of the British Electrical and Allied Industry have won high regard throughout the world, but in these days of increasing international competition, British manufacturers are wise if they refuse to take for granted that potential buyers overseas know as much as they should of the equipment and service which the electrical industry can offer.

THE BEAMA JOURNAL continues to provide, as it has done for many years, a regular link between the industry in this country and its actual and potential customers overseas. The comprehensive BEAMA Catalogue in five languages, of which the 4th edition was issued this year, is another of the many channels through which the industry regularly tells its story in the overseas markets.

This year, however, there have been exceptional opportunities for making direct personal contacts with overseas buyers which the British Electrical and Allied Industry has used to the full.

The Universal and International Exhibition at Brussels —the first event of its kind since the war—presented a challenge to British industry, and the BEAMA took the initiative in ensuring that the achievements and potentialities of the electrical and allied industry were fittingly emphasized in this unique world shop window.

The Industry's exhibit at Brussels has been described in previous issues of THE BEAMA JOURNAL and our next issue (February 1959) will include a complete and fully illustrated record of the Industry's efforts during the six months of the Brussels Exhibition from April to October this year. The Brussels exhibit highlighted British achievements in the field of electricity generation, distribution, and utilization, with an effective presage of things to come.

In May the BEAMA organized the 1958 British Electrical Conference—the only major British conference held in Belgium during the period of the Exhibition—at which the spotlight was turned on Britain's achievements in two specific fields: world communications and nuclear power. The papers presented by Sir Gordon Radley, KCB, CBE, PhD, MIEE, Director-General of the British Post Office ('Communications between Nations and between Peoples'), and Sir John Cockcroft, OM, KCB, CBE, FRS, Member for Scientific Research, United Kingdom Atomic Energy Authority ('Nuclear Energy—the Power of the Future'), surveyed Britain's important contributions to world progress in two widely different aspects of the Industry's work, but with a common link in that they are both concerned with fields of endeavour in which tremendous strides are being made for the benefit of mankind.

Since Sir Gordon's paper was read in May, a far-reaching project to link the Commonwealth by a round-the-world telephone cable has recently been approved in principle. This tremendous venture will depend on British techniques and engineering resources in manufacturing and laying the new submarine cables and repeaters.

In the field of nuclear energy, Britain is leading the world with an expanding programme of nuclear power generation. Four new stations are now under construction, preliminary work has already started for a fifth, and two more are scheduled for the next phase of the programme. Even more significant is the fact that continuing design and engineering research is steadily increasing the output capacity of Britain's nuclear power stations from the 75 MW of the original Calder Hall design to 500 MW for one of the four stations now being built, and 650 MW for the latest projected new one.

If the Industry's exhibits and the Conference at Brussels were mainly concerned with past and present achievements, the British effort at the Geneva 'Atoms for Peace' Conference and Exhibition in September emphasized very vividly the shape of things to come. The impressive British section—easily the largest in the Industrial Exhibition—formed a most comprehensive and practical display of every aspect of nuclear engineering.

The British nuclear industry was in strength at Geneva, prepared to accept orders for nuclear equipment of all kinds. In the years to come, the export of nuclear equipment will form an ever-increasing part of the British Electrical Industry's output.

1958 will stand out as the year in which the British Electrical Industry reminded the world that Britain pioneered steam power, first introduced electrical power, and still leads in serving mankind in this atomic age.

A Telephone Cable Round the World

In his paper at the British Electrical Conference at Brussels, Sir Gordon Radley said that the objective in the field of communications was 'to enable anyone, anywhere, to pick up a telephone and to speak to anyone else, anywhere else, quickly, clearly and at reasonable cost'.

This objective has been brought a great deal nearer fulfilment by a decision of the Commonwealth Trade and Economic Conference held at Montreal in September. The project—which was approved in principle by the Conference—is nothing less than a telephone cable system which will literally encircle the world.

The cost of the scheme was estimated by its sponsor—Mr Fleming, the Canadian Finance Minister—at £88 m; and it will take ten years to complete. Britain's contribution, both financially and technically, will be substantial; in fact, the new project would hardly be possible without the fruits of British research and the wide range of British technical and engineering resources.

Practically all the cable required for the transatlantic system opened in September 1956 was manufactured in the United Kingdom, with American-made one-way repeaters in the twin deep-sea cables and British-made both-way repeaters in the Newfoundland–Nova Scotia link.

The key to the success of that project was the cable ship *Monarch*, owned by the British Post Office, and the only cable-laying ship afloat capable of laying a cable across the deep section of the North Atlantic in one operation.

A new cable, jointly owned by Britain and Canada, is due for completion in 1961 and will run from Scotland to a new Canadian cable head at Hampden, Newfoundland, then under the Gulf of St Lawrence to Quebec, and onward to the Montreal terminal. From there it will link with the Canadian domestic land line system.

The proposed round-the-world cable would link Britain with British Columbia via the new British cable, and from there would go to Hawaii, where it would meet the twin-cable link with the American Pacific seaboard completed in 1957. On from there to Fanning Island in the Pacific; thence to New Zealand and Australia, and on to Singapore, Chittagong, Colombo, Karachi, Bombay, round the coast of Africa and so back to Britain.

All the submarine cable for this vast project will be of the British lightweight type, with British two-way repeaters, and will also be laid by the cable ship *Monarch*.

Thoughts from Geneva

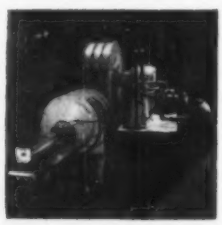
Judged by any standard, the Second United Nations Conference on the Peaceful Uses of Atomic Energy held at Geneva in September was an outstanding success. Britain has every reason to be proud of her major contribution—on the scientific side in the work of the British delegation headed by Sir John Cockcroft and in the quality and number of the papers presented at the Conference; on the engineering side in the size and impact of the British section in the Industrial Exhibition. This was by far the biggest national exhibit and one, moreover, which told a story of experience and achievement and showed in practical form how much Britain has ready to offer to prospective buyers of nuclear plant, equipment, accessories and instrumentation.

The size and complexity of this year's event suggested to many people that some re-thinking and re-planning may well be necessary before the third Conference. To quote the President, Professor Perrin, in his opening address: 'Never have so many representatives, experts, and observers been sent by so many nations to compare work and exchange views on any subject'. Similarly, Sir John Cockcroft said at a press conference that he thought the Conference was too big and too diverse and would be better if it were split up into sections. The recent British and American agreement to lift the security ban and to publish information on controlled thermonuclear fusion is a valuable and timely move and will undoubtedly rank as one of the major successes of the 1958 Conference. While it is apparent that (to quote one speaker) the work done so far on controlled fusion 'has not brought us much nearer our ultimate goal', it is also clear that Britain is at least as far ahead in this field of research as any other country.

Of more immediate importance is the evidence of Britain's continued leadership in the nuclear generation of electricity, and it was convincingly demonstrated in the Exhibition that Britain possesses the technical knowledge, practical experience, and engineering resources which enable her to sell her proved type of gas-cooled, graphite-moderated power stations to any other country that wants them.

Behind that brief statement, however, lies the story of the fine achievements by the British 'consortia'—groups of the leading firms combining the specialized knowledge and experience essential for the construction of commercial nuclear power stations—which have resulted in the great increases in efficiency and power output of the new stations for which they are responsible. It was therefore a pity that the Conference arrangements included their papers in the programme only as references in an Atomic Energy Authority paper entitled 'Current Redesigns of Calder Hall'. This tended to overshadow the very valuable and important contributions which these groups of private firms have made at their own initiative and expense in the way of research, design, and engineering.

The radioisotope sessions covered a wide field, but the emphasis on their medical and biological applications—important though these are—may have tended to overshadow their equally important and widespread uses in industry and industrial research. That the world also looks to Britain in this field is borne out by the fact that, with sales of radioisotopes now running at the rate of £650,000 a year, of which 60 per cent are exported, this country is the largest world exporter of these products.



Cover illustration. *Fuel elements for the new Hinkley Point nuclear power station were one of the exhibits on the stand at Geneva of the English Electric–Babcock & Wilcox–Taylor Woodrow atomic power group. Our picture shows a specially designed air-pressure test rig used by The English Electric Co Ltd to measure the pressure drop across the helical-finned surface of one of these fuel elements.*

British Electrical Industry's Triumph at Brussels

LAST month brought to an end the six crowded and eventful months of the Brussels International and World Exhibition. Looking back over all that has happened, a first judgment must be that the courage and foresight of those responsible for the conception and organization of the British representation has been overwhelmingly justified. The British Government Pavilion and the contribution by British commercial firms, who shouldered the major part of the effort and expense, have been acclaimed by competent observers and visitors from every country of the world.

The British Electrical and Allied Industry's collective exhibit—the largest single exhibit in the British Industry Pavilion—has been an outstanding example of co-operative effort by BEAMA member-firms and the trade associations concerned, resulting in a most impressive portrayal of the achievements of the Industry.

Nearly 42 million visitors went to the Exhibition during the six months between April 17 and October 19; about 4½ million people went through the British section, and about 3 million (at a conservative estimate) visited the British Electrical and Allied Industry's stand.

The success of this collective effort by the Industry was finally crowned by no fewer than 15 awards, including 2 Grand Prix—the highest possible award in any class. The full list is as follows, and details are given below:

2 GRAND PRIX **3 DIPLOMAS OF HONOUR**

3 GOLD MEDALS **3 SILVER MEDALS**

4 BRONZE MEDALS

The Industry's exhibit was visited by industrialists and trade delegations from nearly every country in the world. In addition to the inquiries which were dealt with on the stand, over 900 were recorded and sent to all the supporting firms and associations. These inquiries embraced every section of the industry and originated from visitors from over 50 different countries.

Highlights from the Exhibition diary were the visits of HRH the Duke of Edinburgh in July (reported in our August issue) and of HRH Princess Margaret during the last week of September (see pages 142 and 143). A week later the stand was honoured by a lengthy visit from HM King Baudouin of the Belgians, who inspected all the exhibits with great interest.

Other royal visitors during the run of the Exhibition included HRH The Duke of Kent; HRH Prince William of Gloucester; HM Queen Elizabeth of Belgium; SAR Le Prince de Liège; HM The Queen of the Netherlands; TM the King and Queen of Greece; Princess Birgitta of Sweden; TM the King and Queen of Nepal; The Heir Apparent of Bahrein.

Among many other distinguished visitors from overseas countries were: M. Polacek, Vice-President of Czechoslovakia; M. Paul Struye, President of the Belgian Senate; M. Gaston Eyskens, Prime Minister of Belgium; Mr T. Drouin, Speaker of the Canadian Senate; Mr Shangiti, Speaker, House of Representatives, Sudan Parliament; M. Chizhov, Deputy Minister of Power Stations, USSR; Dr Tom Ingledow, President, British Columbia Electricity Corporation, Vancouver; Dr J. Dorofeet, Academy of Sciences, USSR; Mr J. M. Magowan, Chief Electrical Engineer, Electricity Supply of Southern Rhodesia; The Minister of Commerce, Iran.

The Exhibition is over—but its end is not yet, nor can its results be fully assessed. The impressions of Brussels will remain in the minds of the millions who visited it for a long time to come and will inevitably influence their thinking. In no other way could Britain have made personal contact with so many people and left such a lasting and favourable impression of British enterprise and the British way of life. British industry in general, and the Electrical and Allied Industry in particular, has seized the opportunity which Brussels offered and has benefited to the full.

DETAILS OF AWARDS AND CLASSES

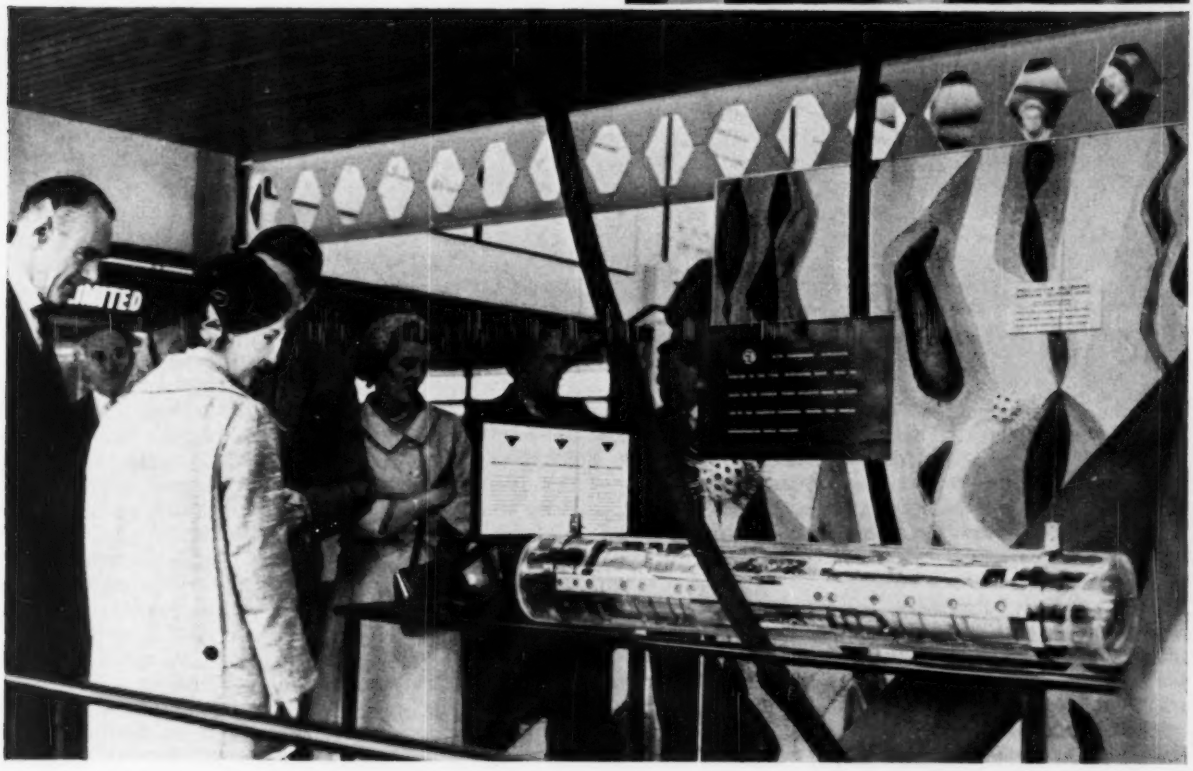
Grand Prix	11/1 Production of Electrical Energy
Grand Prix	11/2 Coordination of Production and Transmission of Electricity
Diploma of Honour	11/3 Distribution of Electrical Energy
Gold Medal	11/4 Applications of Electrical Power in Industries & Professions
Gold Medal	11/5 Domestic Uses of Electricity
Diploma of Honour	11/6 Construction of Generating and Distribution Equipment
Gold Medal	11/7 Construction of Equipment Using Electrical Power
Silver Medal	12/2 Utilization of Water Power
Diploma of Honour	13/2 Exploitation of Nuclear Energy
Bronze Medal	20/9 Welding
Silver Medal	37/4 Lighting
Bronze Medal	38/2 Teletransmission by Wire
Bronze Medal	38/4 Domestic Applications of Wireless Teletransmission
Bronze Medal	38/6 Remote Control
Silver Medal	39/1 Rail Transport

During the ten minutes that she spent visiting the British Electrical and Allied Industry's Stand at Brussels, HRH Princess Margaret showed great interest in the Domestic, Radio, and Television Section, where she inspected the modern types of British electric domestic appliances which were on show. In this picture Princess Margaret is about to descend the staircase leading from the Domestic Section to the centre of the ground floor of the Stand

HRH Princess Margaret at Brussels

(Right) *Princess Margaret's attention was attracted by the section of the Stand which tells the story of hydro-electric power, and she is here looking at the model of the Priest Rapids hydro-electric scheme which a British firm is constructing in the USA*

(Below) *This picture shows Her Royal Highness studying the full-sized model of a British-made two-way repeater of the type which, in conjunction with British-made submarine cables, will be used in the projected round-the-world Commonwealth cable link*



Geneva: Second United Nations Conference on the Peaceful Uses of Atomic Energy

THIS mammoth event, which drew some 6000 scientists to Geneva during the first fortnight of September and which, through the medium of the press, radio, and television, focused the eyes and ears of the world on its theme of 'Atoms for Peace', epitomized the tremendous progress which has been made since the first Conference of its kind was held in Geneva in August 1955. Never before has there been such a comprehensive and impressive display of nuclear equipment and engineering as was to be seen at the industrial exhibition in the Palais des Expositions and the scientific exhibition in the Palais des Nations which was designed to supplement and illustrate the proceedings at the Conference itself.

The major exhibition in the Palais des Expositions represented an undoubted triumph for the British nuclear industry. Out of 360 exhibitors drawn from 13 countries, the British exhibitors made up about one-quarter of the total, and the British Section, with 47,500 square feet (4400 m²), was by far the biggest national exhibit and nearly 50 per cent larger than the French and the USA sections, which came next in order of size. It was also particularly notable for the manner in which the whole section had been made into a complete entity by the ingenious use of large 'GB' plaques, each 12 feet (3·7 m) square, and a specially made red carpet covering all the gangways throughout the British section, giving an effect of unity and making each stand an integral part of a most impressive display.

The British Industry exhibit was coordinated and organized by the Nuclear Energy Trade Associations Conference (NETAC), of which the BEAMA is a founder member and a very active constituent. Many BEAMA member-firms had stands, and although BEAMA itself was not exhibiting, it played an important part in the organization of the British Section.

High Proportion of British Papers

The official United Kingdom delegation to the Conference was led by Sir John Cockcroft, Member for Scientific Research, United Kingdom Atomic Energy Authority; the other members were Sir Leonard Owen, managing director of the UKAEA Industrial Group; Dr Willis Jackson, representing British industry; Sir George Thomson, nominated by the Royal Society; and Dr J. F. Loutit, of the Medical Research Council.

During the course of the Conference, which worked mainly in five simultaneous sessions covering respectively physics, reactors, chemistry, isotopes, and safety, 87 British papers were selected for oral presentation out of the 200 submitted. From all the countries participating in the Conference, over 2000 papers were submitted, of which about one-third were read.

The general sessions during the early part of the Conference were mainly concerned with the future of nuclear power and the possibilities of controlled thermonuclear fusion, and it emerged from many of the papers that the application of nuclear power is proving more expensive than was thought at the first conference three years ago.

Sir John Cockcroft estimated that by 1970 there would be nuclear power stations in operation with a total installed capacity of at least 15,000 MW, but referred to the remarks made in other papers in this group about the various factors—financial, economic, technical, and geographical—which influenced the time when nuclear power might become competitive in different countries.

Britain's Lead in Nuclear Power Generation

From the reactor sessions it became obvious that Britain and France are still the only countries with national programmes for the construction of nuclear power stations. So far as Britain is concerned, the reason for this state of affairs is largely economic, as was made clear in the paper by Mr W. Strath (UKAEA). He pointed out that the demand for energy was already well in excess of the amount that could be supplied from indigenous sources, and this, coupled with the high price of coal and oil, the existence of an integrated distribution system, and the country's technological capacity, made it natural that the UK should be the first country in the world with a long-term programme for the commercial development of nuclear power. The present programme covered the installation of 5000 to 6000 MW by 1966, and if the fall in capital costs could be maintained, it might be extended to 20,000 to 30,000 MW by 1975.

Long-term research and development were therefore aimed at lowering the cost of electricity produced in large stations and at developing systems capable of operation in smaller sizes. He indicated that the now familiar gas-cooled, graphite-moderated practice was the road they would follow, but they were giving particular attention to the gas-cooled, heavy water moderated system which, it was believed, would be capable of producing electricity more cheaply than the early civil stations and would be simpler and easier to maintain than the high temperature gas-cooled reactor and the sodium-cooled fast reactor. The gas-cooled, heavy water moderated reactor, and a further development of the Calder Hall type of reactor, were being considered for development as medium-sized units. By the 1970s it might be possible to use the high temperature, gas-cooled reactor using highly enriched ceramic fuel in a solid moderator, in conjunction with a gas turbine.

This was further developed in a paper by a team from Harwell, which revealed the project as an extremely advanced design to operate at about 750 deg C, using all-ceramic elements on a thorium 232/uranium 233 breeding cycle and cooled by helium. The proposed 10 MW reactor experiment also incorporates an ingenious idea of a free-running gas turbine/blower set, with the heat

rejected from the turbine fed to a heat exchanger for further utilization.

The advanced gas-cooled reactor was briefly described in part of a paper by a team from Risley. The prototype of this machine is to be built at Windscale and is scheduled for completion in 1961. The fuel will be uranium dioxide canned in beryllium and the reactor will be cooled by carbon dioxide. The principal data were given as: reactor heat output 100 MW; net electrical output 28 MW (approximate); maximum can surface temperature 600 deg C; gas pressure and temperature at reactor inlet: 270 lb/in² (19 kg/cm²) and 250-325 deg C; bulk gas outlet temperature 500-575 deg C; mean fuel rating 7·75 MW/tonne; maximum fuel rating 18·0 MW/tonne; steam conditions 620-670 lb/in² (43·6-47·0 kg/cm²) and 860 deg F (460 deg C).

The main part of this paper dealt with advances in the design of gas-cooled, graphite-moderated power reactors, describing the lessons learned from Calder Hall and then discussing the future of this type of reactor, with particular reference to fuel cycles, slightly enriched reactors, oxide fuels and high temperature operation, and the conclusion can be drawn that the advanced gas-cooled reactor will provide the same basis for the next family of reactors to be built in the UK that Calder Hall has done for the new stations now being built in this country.

As is now well known, an important feature of these new stations is the considerable increase in output as compared with Calder Hall, and one of the significant factors in this development lies in improved fuel element design. Several papers contributed by the British consortia revealed the important work carried out in this field by their nuclear design groups.

Another paper contributed by the UKAEA dealt with the Authority's methods of assessment and testing of fuel element designs and described the proving of production techniques and non-destructive testing methods.

The economics of nuclear power were discussed in a short session which produced two valuable papers from J. F. Jukes (UKAEA) and J. C. Duckworth and E. H. Jones (CEGB and South of Scotland Electricity Board respectively). The figures presented to the 1955 Conference by Mr Jukes have been widely used since then for calculating the probable cost of nuclear generation of electricity in Britain, and in his paper at this year's Conference Mr Jukes showed how and why the original cost assessments have altered during the last three years.

He discussed such factors as the great increase in technical knowledge; experience in the design, building, and operation of various research reactors and in the design and construction of commercial power stations; research and development costs as an item in the final cost of power from a nuclear station; fuel costs, and so on. The most important single factor under this last item is that of fuel 'burn-up', which for the early commercial stations was given as 3000 MW-days per tonne, while improvements in design and fabrication methods were now thought likely to lead to lower fuel replacement costs and higher performance, although this is also tied up with the figure of plutonium credit.

The stand of the AEI–John Thompson Nuclear Energy Co Ltd. On the left is a model of the Berkeley nuclear power station now under construction by the group, and in the centre is a sectioned picture of 'Sceptre'—the experimental thermonuclear fusion assembly at the AEI research station at Aldermaston

Comparing the 1955 and 1958 estimates given in the paper shows that the earlier figures were, on the whole, very soundly based, and that the increase shown in the later figures, even allowing for the much smaller plutonium credit brought about by the lower price of natural uranium and American uranium 235, is due to the rise in interest rates and the inclusion of site development charges—the latter amounting to anything from 5 to 10 per cent of the capital cost and adding 0·04 d/kWh to the cost of electricity.

The second paper gave a more detailed analysis of the costs of the new British nuclear stations in the programme for the next eight or nine years, pointing out

that the total generating costs of the first three stations—Berkeley, Bradwell, and Hunterston—will be marginally greater than a modern high fuel-cost station, while Hinkley Point—the latest of the first group of four new stations—will be marginally less than that of a coal-fired station completed at the same time on a site distant from the coalfields. Both estimates assume a conservative load factor of 75 per cent, although there is an adequate base load on the system to operate these stations at 100 per cent load factor if it is technically possible.

They assessed future costs on the basis that engineering improvements should enable the capital cost (without initial fuel charge) of Hinkley Point—£120 per kW of net electrical output—to be reduced to £100/£110 per kW for stations to be completed in 1965/66. In the next phase—1967/70—the capital cost of an 800-MW station with a single highly-rated gas-cooled reactor using beryllium/oxide fuel elements would have been brought down to £85 per kW, while a two-reactor 1600-MW station would have a capital cost of £75 per kW. Providing nuclear fuel costs do not rise in the meantime, the total generation costs would then be as low as 0·45 to 0·5d per kWh sent out. A significant reduction in the generating costs of conventional stations during the same period was not thought to be likely.

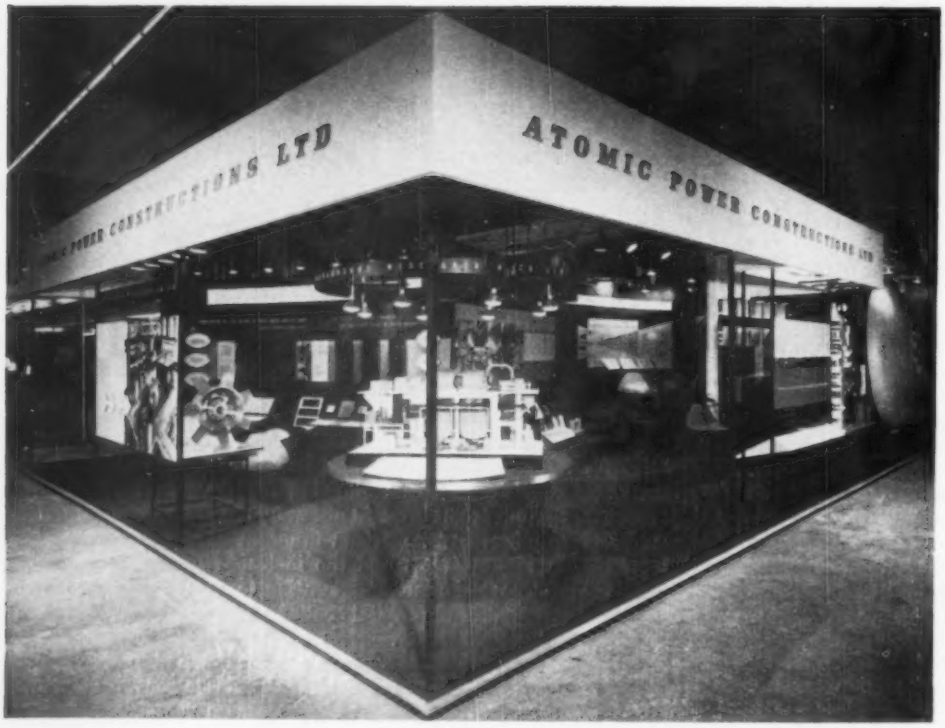
The paper recorded the belief that it would be possible to operate some 7000 MW of nuclear plant on base load at 75 per cent load factor or higher in 1965, but if installation after that date were to be continued at a greater rate than 400 MW a year, nuclear plant would have to be competitive at lower load factors.

Papers and discussions on reactor fuels and materials spread over seven sessions and revealed that a tremendous amount of research has been carried out since the first conference on fissionable elements, and much valuable data have been amassed on the irradiation properties of uranium and uranium alloys with a view to controlling harmful effects and prolonging irradiation life without fuel element failure.

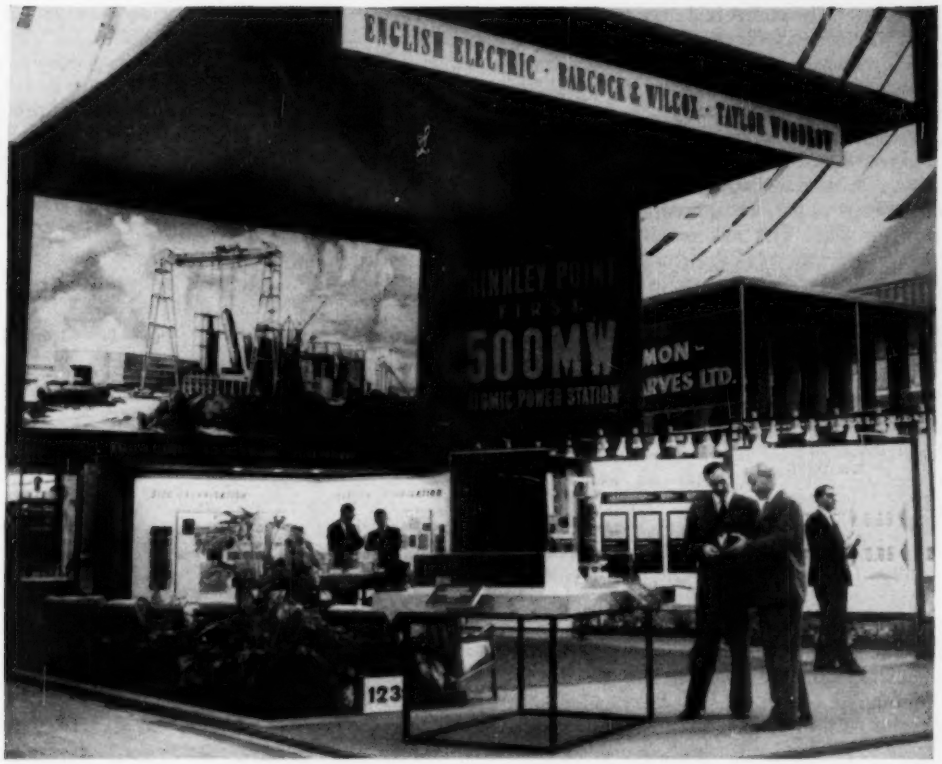
One of the many UK papers presented at these sessions was of particular interest in view of the intention to increase the operating temperature of the later Calder Hall type of reactors and the new advanced gas-cooled reactor. This paper recounted the investigations carried out at Harwell into the corrosion resistance of beryllium in carbon dioxide and showed that, in the presence of wet carbon dioxide, breaking corrosion begins after 400 hours at 600 deg C, but that rapid corrosion does not occur in dry gas below 650 deg C. These findings indicate that corrosion in beryllium is unlikely to limit the life of a fuel element provided the sheath temperature does not exceed 600 deg C and that the moisture content of the gas is kept low.

The paper also discussed the difficulties in fabrication—particularly welding—when beryllium is used as a sheathing material and described various methods of 'integral canning' which have been investigated. Forging of a composite unit consisting of a metallic uranium core surrounded by a tamped layer of beryllium powder in dies at pressures of 50 tons/in² (7900 kg/cm²) at a temperature of 1000 deg C has been found successful, but the most promising method would seem to be co-extrusion, for which a blind hole is drilled in a cylinder of beryllium, the uranium fuel inserted, the hole closed by a plug, and the composite unit extruded at about 500 deg C. Elements of this type have successfully withstood thermal cycle and irradiation tests.

Irradiation creep was dealt with in another UK paper describing the investigations undertaken into this phenomenon at Windscale, with particular reference to the



This is the stand of the newest of the British consortia — Atomic Power Constructions Ltd. Details of the exhibits are given on page 148



The stand of the English Electric–Babcock & Wilcox–Taylor Woodrow consortium was dominated by pictures of the Hinkley Point power station now being built by this group

performance of the Calder Hall reactors. The Windscale tests were reported to have confirmed the extent of the effect as predicted by the early experiments, and have enabled a remedy to be found in lateral braces of magnesium alloy in the middle of the fuel element. These have satisfactorily restricted bowing of the elements at the irradiation doses so far experienced. It was reported that only 13 fuel elements have failed out of about 30,000 inserted, and most of these failures could be attributed to defective welds or other manufacturing faults.

The design and manufacture of the fuel elements for the Dounreay fast breeder reactor were described in a paper by C. J. Turner and L. R. Williams. These have many special features, of which an important one is the incorporation of a safety device to enable the uranium to be removed from the core in a controlled manner in the event of a power excursion which might otherwise increase the criticality of the assembly.

Mention must be made—however briefly—of the series on isotopes and biology, which covered no less than 17 sessions. The majority of the papers were concerned with medical and biological aspects, and the UK was well represented in this field with 11 papers accepted for presentation.

This left only a comparatively small proportion of papers dealing with the uses of isotopes in research and industry. Britain was equally well represented among the papers presented on these subjects, and mention must be made of one describing the application of radiotracers to the measurement of engine wear in moving vehicles, and another on the applications of fluorescent X-ray production by electron capture isotopes—a novel and potentially valuable non-destructive method of analysis based on the fluorescent excitation of the characteristic X-radiation of the sample and examination of the fluorescent radiation by a proportional counter and pulse analyzer.

Instrumentation was not included as a separate session of the Conference (although it formed an important section of the Exhibition). However, papers dealing with this subject were included in the appropriate sessions and discussed the instrumentation aspects of the session theme.

Health and safety were the subjects of several papers, notably three from the UK, one describing the apparatus and technique of using a whole-body monitor to determine the degree and distribution of contamination in the body of exposed persons; another dealing with the control of health hazards in handling plutonium; and the third (by EMI Electronics Ltd) describing their hand and clothing monitor.

Thermonuclear fusion was discussed both in the general sessions and in 18 of the technical sessions. With the declassification by the United Kingdom and the USA of all work on controlled thermonuclear fusion, and the presentation to the Conference by the USSR delegates of five volumes covering their work to date, it became apparent that all three countries have been working on very similar lines, and that in no country has there yet been found any real answer to the massive problems involved.

In his paper, Dr Thonemann of the UKAEA said that in Britain the method represented by ZETA was considered at the moment to be the most promising. In his opinion, the question of whether electric power could be generated using light elements on their own would be answered in the next decade, and it would be another ten years before it was known whether such a power source was economically valuable.

The UKAEA has announced that it proposes to move

the whole of its controlled thermonuclear work from Harwell to Winfrith Heath during 1961–63, a move which will permit the development of both fission and fusion projects at Winfrith with room for whatever expansion of the latter may be necessary.

At a press conference in Geneva, Sir John Cockcroft said that by that date the number of scientists working on fusion in the AEA would have been doubled. The present number was 100, compared with 500 working on other projects. Their first task now was to study the information that had been revealed during the Conference. Modifications would continue to be made to ZETA I as required. ZETA II—on which certain work had already begun—would be built at Winfrith Heath.

The British Exhibits

The British Section in the Industry Exhibition staged in the Palais des Expositions was, as mentioned earlier in this review, by far the biggest national exhibit, and comprised 86 organizations who are able and ready to design, build, and commission nuclear power stations and to supply all the instrumentation in any part of the world. Here is a brief review of the principal exhibits.

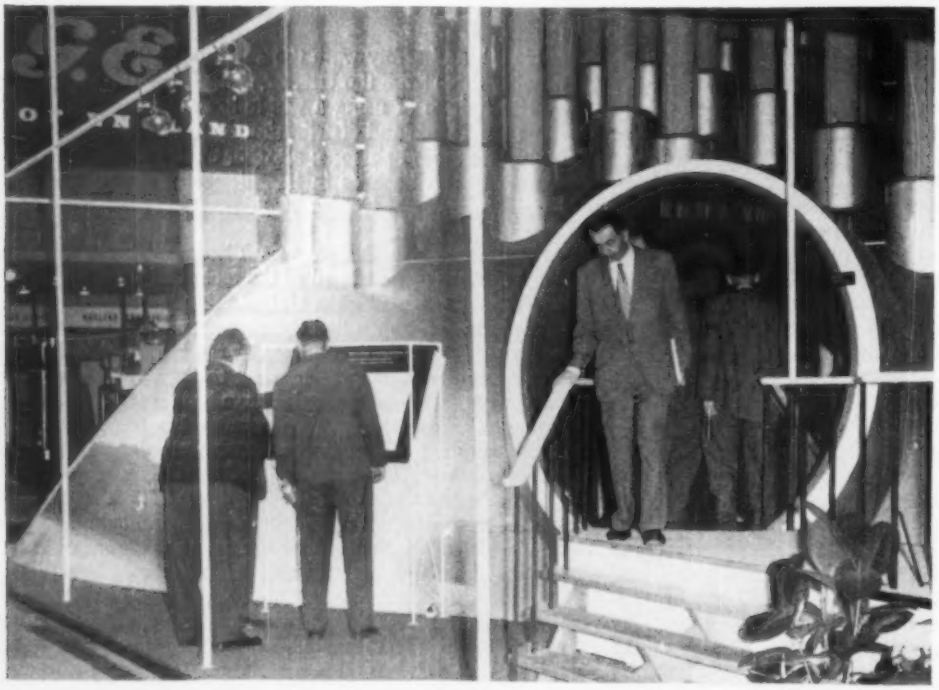
The display by the United Kingdom Atomic Energy Authority demonstrated the world-wide service offered by the various establishments of the Authority—of which perhaps the best known is the sale of radioisotopes for medical, industrial, and research purposes, and the accompanying advisory service.

The Authority is the largest exporter in the world of radioactive isotopes, and the exhibit included representative examples of several hundred types. A summary of their production processes and uses was given by means of multi-language films and animated diagrams.

Another world-wide service of the UKAEA is the supply and processing of fuel elements, and here again this was portrayed in models, films, and animated diagrams, together with a survey of fuel element evolution over the past decade.

Atomic Power Constructions Ltd is a new consortium of companies which made its debut at Geneva. It comprises the following firms, each well known in its own field: Crompton Parkinson Ltd, Elliott Brothers (London) Ltd, Fairey Aviation Co Ltd, International Combustion (Holdings) Ltd, Nuclear Civil Constructors (Trollope & Colls Ltd and Holland & Hannen and Cubitts Ltd), and Richardsons Westgarth Ltd. The group exhibit was a complete model of a typical 500 MW nuclear power station, while the principal exhibits of the constituent firms were: an 'exploded' self-regulating alternator with a 'Magnicon' exciter mounted on the alternator shaft (Crompton Parkinson); a 54-point scanning recorder which enables voltages from 54 different sources to be recorded on a single chart (Elliott Brothers); atomic fuel containers for Calder Hall, a nuclear magnetic resonance spectrometer of medium-high resolution, and a filter for use in hydraulic pressure lines up to 4000 lb/in² (281 kg/cm²) filtering particles down to 0·004 mm in size (Fairey Aviation); parts of a heat exchanger for a gas-cooled, graphite-moderated reactor (International Combustion); photographs of a plutonium separation plant (Nuclear Civil Constructors); a model of a turboalternator set specially designed for the steam conditions in a nuclear power station, and a bladed blower rotor which is being developed for use in the carbon dioxide circuits of reactors (Richardsons Westgarth).

The Nuclear Power Plant Co Ltd—the consortium responsible for the Bradwell power station now in course of construction—showed a sectioned and animated model of a nuclear power station with two gas-cooled, graphite-moderated reactors, with a descriptive commentary in English, French, German, Italian, and Russian. Displays by the constituent firms of this group included the following. A model of steam-raising equipment



A feature of the stand of the General Electric Co Ltd (in association with Simon-Carves Ltd) was this full-sized model of a section of a reactor which visitors could enter through one of the gas ducts

(Clarke, Chapman & Co Ltd); samples of structural steelwork (Alex Findlay & Co Ltd); a model of a cooling tower (Head, Wrightson & Co Ltd); a model of a reactor under construction (Sir Robert McAlpine & Sons Ltd); a model of a 100 MW turbogenerator—a multi-cylinder type with high-pressure and double-flow low-pressure cylinders coupled to a single generator (C. A. Parsons & Co Ltd); a model of a typical feeder circuit of a 132 kV duplicate busbar switching station, and a full-size sectioned head of a 275 kV air-blast circuit-breaker (A. Reyrolle & Co Ltd); a model of an electrically controlled fuel element grab operating in a section of the graphite core of a reactor (Strachan and Henshaw Ltd); samples of welded seams of pressure vessels (Whessoe Ltd).

The Nuclear Power Plant Co Ltd featured on this stand a sectioned and animated model of the Bradwell power station which this group is now building

The next stand was that of the AEI–John Thompson Nuclear Energy Co Ltd and was occupied by three members of the consortium—Metropolitan-Vickers Electrical Co Ltd, the British Thomson-Houston Co Ltd, and John Thompson Ltd, and three associated companies—Isotope Developments Ltd, Sunvic Controls Ltd, and Nuclear Graphite Ltd. The major exhibits here were a model of the Berkeley 300 MW nuclear power station now being built by the consortium; a model of Sceptre III —the thermonuclear fusion assembly at the AEI research station at Aldermaston; a model of the 'Merlin' research reactor; and a model of an advanced 150 MW nuclear power station which is available for export.

The BTH exhibit included an electromagnetic pump for liquid metals such as sodium; a full-size model of an ignitron valve as used in ZETA; descriptive drawings of an actuator mechanism for control rods in a reactor; and a model of a 4000 hp gas circulator, sixteen of which are being supplied for the Berkeley power station.

Metropolitan-Vickers contributed a series of photographs of a 25 MeV electron linear accelerator built for the UKAEA, a mass spectrometer, and a Newton-Victor 'Orbitron' therapy unit using a cobalt 60 source. Exhibits by associated companies included a scintillation counter particularly suitable for measurements on the human body, a gamma radiation alarm giving visual or audible warning, a portable level detector for checking the contents of gas bottles, and a package monitor for checking containers on a high-speed production line (Isotope Developments Ltd); complete instrumentation for power and research reactor control, a data handling system with magnetic memory storage drums capable of memorizing 500,000 numerals and suitable for analyzing the output of scintillation counters used for burst cartridge detection equipment and for temperature monitoring and recording of control rod positions (Sunvic Controls Ltd).

The world's largest nuclear power station—the 500 MW plant now being built at Hinkley Point in Somerset —was shown in an advanced stage of construction by a giant colour transparency on the stand of the consortium comprising the English Electric Co Ltd, Babcock & Wilcox Ltd, and Taylor Woodrow Ltd. Detailed models illustrated the layout of the station when completed, a sectioned reactor and heat exchanger, and technical displays emphasized the special features contributing to the high heat output and steam generating efficiency of the station, and the research and development work carried on by the group on fuel element cans, the corrosion of metals in dry carbon dioxide, and the

thermal cycling of uranium through the alpha-beta transformation.

The Atomic Energy Group formed by the General Electric Co Ltd in association with Simon-Carves Ltd is now building the new 320 MW nuclear power station at Hunterston in Scotland, and an outstanding feature on this stand was a full-scale model of a section of a gas-cooled, graphite-moderated reactor which visitors could enter through one of the gas ducts and examine the constructional details of the reactor core, the double-shell pressure vessel, fuel elements, control rods, and gas sampling equipment.

An illuminated schematic diagram showed the layout of a high-temperature gas-cooled zero energy experimental assembly which is being built for the UKAEA, and other exhibits included an animated diagram of a burst cartridge detection system, and a demonstration of the properties of impermeable graphite.

The GEC heavy duty, power operated, remotely controlled manipulator for handling radioactive and toxic materials attracted considerable attention on this stand.

Hawker Siddeley–John Brown Nuclear Construction Ltd portrayed in their exhibit the group's resources covering the complete field from feasibility studies through research, development, and design to the complete construction and commissioning of nuclear power stations and nuclear ship propulsion plant. Specific exhibits included a model of 'Jason'—a 10 kW research and training reactor with facilities for internal and external exponential experiments, a representation of an advanced plant for the production of heavy water, and the reactor kinetics section of an analogue computer designed for evaluating the effects of eleven delayed neutron groups.

Instrumentation

Although the stands of the consortia commanded attention by virtue of their size and the variety of the exhibits by their constituent firms, they had by no means a monopoly either of interest or technical achievement, as the following review of the highlights of individual exhibits by BEAMA member-firms will reveal.

A full-size heating unit and ebullition chamber used in purifying sea water for nuclear stations was shown by Aiton & Co Ltd together with examples of advanced pipework with very thick walls and expansion fittings up to 42 inches (107 cm) internal diameter.

The Cambridge Instrument Co Ltd naturally had an extensive display of specialized instruments, notably a rod speed recorder for the testing of emergency shutdown arrangements, an electro-chemical dissolved-oxygen analyzer, a carbon dioxide purity indicator and alarm system, and a universal vibrograph for measuring vibrations or rotational velocities.

The neighbouring stand was occupied by Ekco Electronics Ltd with a wide range of instrumentation for reactor control, and nucleonic equipment for use in industrial and medical research. In the first category were some of the latest instruments for the firm's installations of instrumentation and control circuitry for heavy water research reactors both in Britain and overseas, and other equipment shown included nucleonic gauges for non-contact measurement and control of the thickness of sheet materials and coatings, scintillation counters, rate-meters, radiation monitors, and similar equipment.

In addition to their participation in the group exhibit of Atomic Power Constructions Ltd, Elliott Brothers (London) Ltd also had an individual stand devoted to nuclear plant control instrumentation, and an analogue reactor simulator giving an accurate indication of reactor behaviour in real time and demonstrating the effect of varying conditions in reactor operation.

EMI Electronics Ltd showed their specialized hand and clothing monitor which was the subject of a paper presented at the Conference. It uses four large-area scintillation counters with special dual scintillators to detect simultaneously alpha and beta contamination on both hands, and is claimed to reduce the hand count time to five seconds. Two clothing probes attached to the cabinet give separate indications of alpha, beta, and gamma levels. The exhibit also included oscilloscopes, millimetre wave generators, and photo-multipliers.

'Mercury'—the high-speed digital computer claimed to be capable of solving problems up to 50 times faster than any computer made in Western Europe—was the main feature of the stand of Ferranti Ltd, but they also had an interesting exhibit of their diffraction grating measuring equipment applied to the photo-electric detection and conversion of moiré fringe patterns into electrical impulses in conjunction with dekatron counters.

Laboratory and Research Equipment

Nucleonic instruments were shown by General Radiological Ltd, one of the principal exhibits being a complete power station neutron flux measuring installation designed for one of the new power stations now under construction. Instruments representative of the company's activities in fields of health physics and laboratory research were also shown, together with a display of isotope handling equipment.

Mitchell Engineering Ltd showed a scale model of a 17·5 MW nuclear power station with a closed-cycle boiling water reactor, and illustrations of the firm's nuclear engineering work at Chapelcross, and at the Dounreay, Capenhurst, and Springfield installations.

Principal exhibits by Mullard Equipment Ltd were a model of a 4 MeV electron linear accelerator for the irradiation of materials on a production basis; a working display of a system of safety circuits for nuclear reactors using solid state devices, and an ultrasonic drill for drilling uranium.

The Pye Instrument Group had a very wide and comprehensive range of nucleonic, electric, and electrical instruments marketed by the companies in the Group, including equipment for health monitoring and medical applications; electrical measuring instruments and test sets; spectrophotometers and crystallographic instruments for chemical analysis and quality control.

Two master slave manipulators were shown, with a lateral displacement motion which enables the slave arm to be displaced by 30° with respect to the master arm. This gives better coverage and makes it unnecessary for the operator to move from side to side. A stereo television camera used in conjunction with the manipulator helps the operator to judge distance. Another camera was a carbon-dioxide-cooled reactor camera with a remotely controlled mirror for photographing round corners.

Henry Wiggin & Co Ltd made a special feature on the stand of the Mond Nickel Co Ltd of their information service on nickel and nickel alloys, backed up by displays dealing with the heat- and corrosion-resisting metals, controlled thermal expansion alloys, and the cobalt-free characteristics of Mond nickel pellets.

Operating Experience with a Semiconductor-Rectifier Multiple-Unit Train

J. A. Broughall, BSc Eng, MIEE,* *and J. C. Read,* DSc, MIEE†

IT has previously been announced that in December 1955 British Railways took delivery of a germanium power rectifier—the first of its kind in the world—for supplying the motive power to a motor coach on the Lancaster–Morecambe–Heysham line. It is felt that the time is now ripe to describe the operating experience with this unit and to give some account of a more recent development, and this is the purpose of the present article.

Germanium Rectifier Unit

The recent development of high-power high-efficiency semiconductor rectifiers derives from the discovery, less than 10 years ago, that a very great advance on the polycrystalline 'dry plate' rectifiers hitherto known could be made by forming the rectifying barrier layer actually inside a single crystal of very high purity material, particularly germanium or silicon. This discovery was quickly followed by the invention of new or greatly improved processes for refining the metal; for growing, testing, and slicing the single crystal; for forming the internal p-n junction; and for many other details. As a result, a 300 kW 270 V germanium rectifier, the first in Europe and at the time the largest in the world, was put into trial service in this country in December 1953, and this was followed in 1954 by a 300 kW 250/500 V unit, and in 1955 by a 1000 kW 255 V unit.

The new type of rectifier appeared likely to prove suitable for motive power service on 50-cycle railway rolling stock. While somewhat more costly than the mercury arc rectifier for such duty, and more sensitive to overloads and over-voltages (though it was felt that these limitations could be guarded against), it offered on the other hand the advantages of (i) much greater simplicity and hence the prospect of better reliability and lower maintenance cost, (ii) freedom from a minimum temperature limit and hence from the need for heating up before starting service, (iii) easier accommodation under the frame in the case of motor-coach duty, and (iv) a useful saving in energy consumption.

The performance of the early installations referred to above exceeded all reasonable expectations, and accordingly, early in 1955, the makers concerned approached the British Transport Commission for facilities to try out a germanium rectifier in a motor coach on their system. The Commission, concerned with plans for major railway electrification in Great Britain, welcomed the proposal. The only existing ac 50-cycle section of line in the country was that between Lancaster, Morecambe, and Heysham, and on this a small number of multiple-unit trains (Fig 1) were already operating, equipped with pumpless air-cooled mercury-arc rectifiers for supplying the dc traction motors. In order to save time the Commission decided to try the germanium rectifier in one of these existing motor coaches by simply removing the mercury arc rectifier and its cubicle and auxiliaries, and substituting the cubicle containing the germanium rectifier.

The germanium rectifier was therefore designed for the same rating, namely 750 kW at 1500 V dc, with a peak current during acceleration of 1000 A. As the existing transformer, intended for use with the mercury arc rectifier, had a single-way (i.e. centre-tapped) secondary winding, the maximum peak inverse voltage across the rectifier was 5000.

The germanium rectifier was housed in a sheet steel cubicle (Fig 2) measuring 3 ft by 3 ft by 6 ft 6 in (90 cm by 90 cm by 200 cm) high, mounted on an angle-iron frame

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Fig 1. 3-coach multiple-unit train on the Lancaster–Morecambe–Heysham line. The motor coach is equipped with a trial semiconductor rectifier

on resilient mountings. In this, the germanium cells were arranged in 12 strings, 6 in parallel on each side of the circuit, each string consisting of 50 cells in series. The connexions are shown in Fig 3. The cells, which were forced-air-cooled, were mounted on 6 vertical trays, 2 strings per tray. The trays were provided with rollers and could readily be withdrawn for inspection or maintenance, as shown in Fig 4.

A high-rupturing-capacity fuse was connected in series with each string of cells, so that in the event of a string developing a short-circuit, this would be cleared by its fuse, thus saving the sound strings from being damaged by the overload current which they would feed into the faulty string. The fuses are shown in Fig 3, and it will be noted that in case of a dc fault such as a motor flashover,

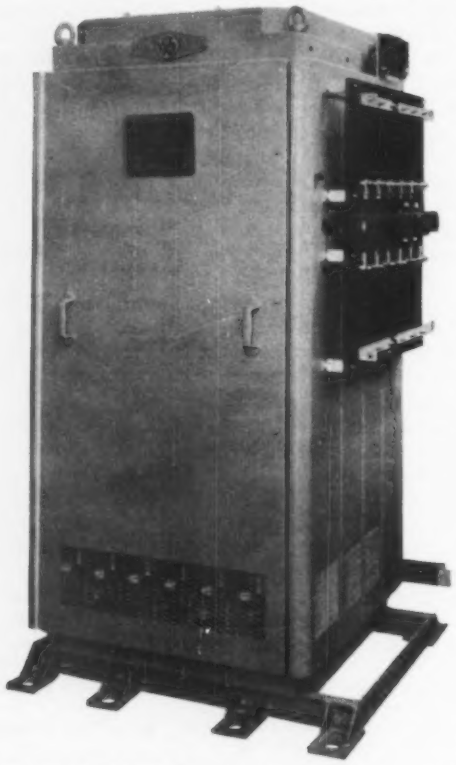


Fig 2. The 750 kW 1500 V semiconductor rectifier used for the trials. (Fuse cartridges removed from the panel)

the short-circuit current of the transformer would be shared among 12 fuses in parallel, so ensuring satisfactory discrimination. As a further part of the coordinated protective scheme it was also necessary to have a rather higher value of transformer reactance than had been provided in the existing mercury arc rectifier transformer, so a separate oil-immersed series reactor was added, as shown in Fig 3.

Indication of any open-circuiting, *e.g.* due to the blowing of a fuse, was provided by current transformers and relays (not shown in the simplified connexion diagram) in the rectifier cubicle, each connected to measure the difference between the currents of two parallel strings of cells. Under normal balanced conditions the current in the secondary winding of the current transformer was thus zero, but any unbalance would cause current to flow in this circuit, energizing the coil of the relay. Operation of this relay opened a normally-closed contact in an indicator lamp circuit, thereby extinguishing the lamp and warning the driver that he must proceed only under reduced power.

Protection against voltage surges was provided by a separately-mounted capacitor connected across the output terminals of the series reactor unit, *i.e.* across the ac terminals of the rectifier cubicle. A 1 megohm discharge resistance was provided across this capacitor.

The rectifier cells, which were of an early type in which the active slice of germanium was protected from the atmosphere by an araldite moulding, were provided with cooling fins (see Fig 4) for forced air cooling. An extraction fan mounted in the top of the rectifier cubicle provided the necessary air flow, the air entry being through grilles at the bottom of the cubicle. The cubicle was simply placed in the train in the same way as the mercury arc rectifier cubicle that it replaced, without any other alteration to the ventilating arrangements—a feature which will call for comment later. A fan failure relay, having its contacts held closed by the fan air pressure, was also mounted in the rectifier cubicle, to trip the breakers in case of a failure of the air flow.

Tests and Operating Experience

The Lancaster–Morecambe–Heysham electric service was suspended during the winter of 1955/56 for alterations to the overhead contact-wire system. Consequently, after brief trials there in December 1955, the train was moved to the London area. There, a section of the 1500 V dc system between Fenchurch Street and Bow Junction was isolated for trials during the night, and supplied instead with 50-cycle ac of the same voltage as on the Heysham line. A series of operation and other tests were then performed.

The most important of these tests was designed to verify that the rectifier fuses would not blow in case of a motor flashover. The master controller was re-connected so that on its final notch, instead of diverting more of the motor field current through a resistance, it applied a dead short-circuit across the field windings. The motors flashed over, and the fault was cleared by the supply circuit breaker on every occasion, without any operation of the rectifier fuses. On subsequent detailed examination the rectifier was found to be completely undamaged.

The train with the germanium rectifier was then put into regular passenger service on the Lancaster–Morecambe–Heysham line when the electric service reopened in March 1956. It ran throughout that year completely without incident and with a record of absolute reliability. In April 1957 the cells were tested individually, and it was found that 3 had developed short-circuits. As the resulting increase of voltage stress across the remaining cells was small, it was decided to leave the three short-circuited cells in service without change.

On the afternoon of Sunday, June 16, 1957, a considerable failure of the germanium rectifier occurred. The train, which had been standing in the sun during an abnormally hot period, was coupled to a second train for the purpose of towing the latter in. As it was moving away, with the controller on the second notch (25 per cent voltage), a loud report was heard and a complete failure of the supply to the traction motors took place. On examination it was found that 7 of the 12 fuses had blown and 10 of the 12 strings of cells had failed ; some

of the cells had blown apart or otherwise become open-circuited, and there were signs of some arcing having occurred across cells and fins. It was also found that during the previous week drivers had reported intermittent operation of the fuse failure indication and, although no fuses were found to have failed, two were reported cool, indicating that intermittent open-circuits or high-resistance joints must have developed at that time in two strings of cells. There was no fault in the transformer, motors, or other apparatus.

The failure naturally led to very careful investigation, and it was found that it had undoubtedly been due to the unsuitable ventilation arrangements, the effect of which was aggravated by the hot weather and by the abnormal load of attempting to haul the other train.

The mercury arc rectifier which this rectifier had replaced had been accommodated in what had formerly been the equipment compartment of the coach (above floor level), and the rectifier fan merely circulated the air in this compartment, without any definite provision for it to draw in cool air from outside. A separate fan (the transformer oil cooler fan) was arranged to draw in outside air to the compartment, but the control scheme was such that neither fan could start till the master controller handles were moved from the 'off' position. When standing idle in strong sunshine the compartment could thus become very hot, and in fact a temperature of 78 deg C had been measured in the rectifier compartment of one of the other trains when standing idle earlier in the same week. Even when the oil cooler fan did start, its effect would be only gradual, because of the large volume of the compartment. This ventilation scheme, when used with the mercury arc rectifier, could assist in preventing overcooling in cold weather, but this is a consideration that does not arise with semiconductor rectifiers. As previously mentioned, the germanium rectifier was installed without any alteration of these arrangements. No excess temperature thermostat in the circulating air was provided.

The sequence of events had therefore been as follows. Whenever the train stood idle for a prolonged period during this hot weather the roof must have been heated by the sun to a very high temperature, while the apparatus in the compartment remained somewhat cooler. Raising the pantograph had no effect on these conditions. Directly the train started to move the fans also started, and their first effect must have been, not to cool the rectifier, but to heat it up by drawing the hot air through it. Germanium rectifier cells can normally stand junction temperatures up to 70 to 80 deg C, which are ample for conditions in this country, but naturally a rectifier unit designed for an ingoing temperature of the cooling air of 30 to 35 deg C is not suitable for ingoing air temperatures of over 70 deg C, especially when combined with overload. This probably accounts for the intermittent open-circuits or high resistances in 2 strings which developed during the week. On the Sunday afternoon when the failure occurred, the train had been standing idle in the sun for an unusually long time, and was therefore particularly hot. The resulting combination of high temperature and overload then caused the remaining strings to fail.*

Steps were at once taken to correct this situation. A thermostat was added in the rectifier cooling air, arranged to prevent operation if the air temperature rose above 40 deg C. The ventilation arrangements were modified by

(*a*) arranging for louvres to be opened in the side of the coach adjacent to the air intake openings in the base of the rectifier cubicle, so that at least some outside air would be drawn into the rectifier directly its fan began to run, and

(*b*) changing the control circuits so that the rectifier and oil cooler fans would run directly the pantograph was raised.

At the same time the opportunity was taken to replace all the germanium cells, including those that were still intact, by the new hermetically-sealed Type GP-C, which were known to be much superior and had in the meantime come into regular production.

These changes were completed within three weeks of the failure, and the train was then immediately put back into regular use.

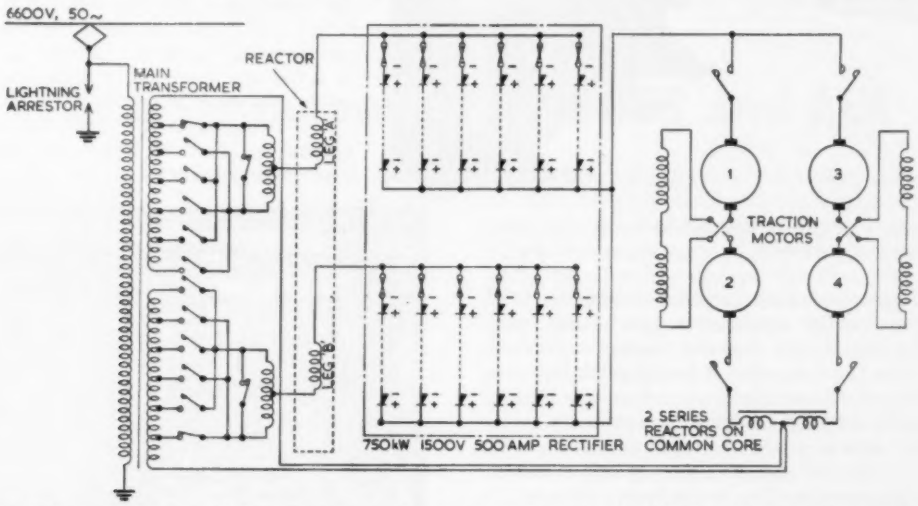


Fig 3. Schematic diagram of the connexions in the motor coach equipped with the trial germanium rectifier

* The new germanium rectifier motor coaches in course of manufacture for the British Railways electrification scheme will have the rectifier cubicle mounted under the coach frame, and had already been arranged to draw their air direct from outside, so the experience of this incident does not affect them.

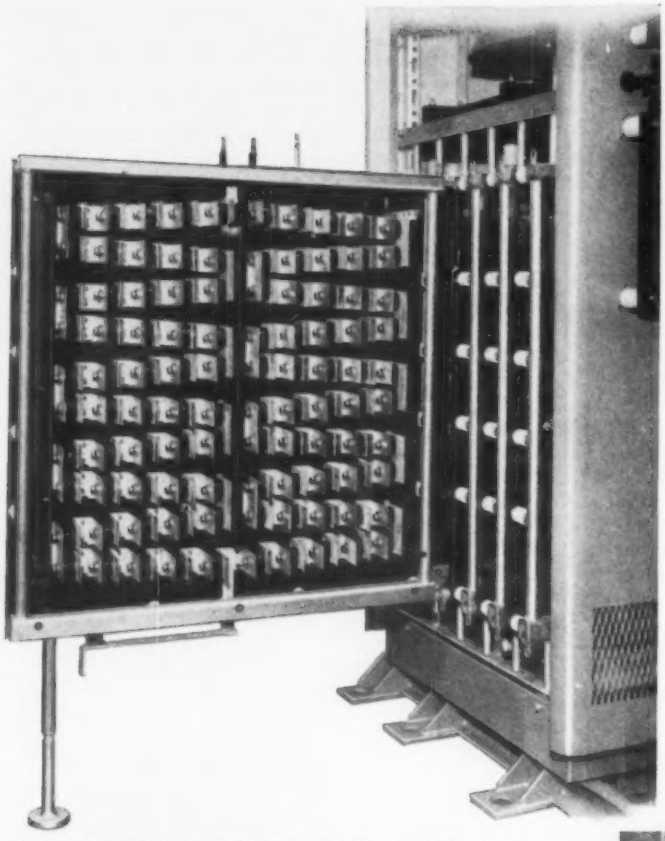


Fig 4. Germanium rectifier tray pulled out and resting on a temporary support strut for inspection or servicing

With the exception of this occurrence on June 16, 1957, the germanium rectifier operated in continuous commercial service without the slightest trouble or incident of any kind from the date when it first started operation in March 1956 till it was taken out of service in June 1958. This period included a week of exceptionally severe thunderstorms, and it would therefore appear that the over-voltage protection given by the capacitor met all reasonable requirements. The breakdown on June 16, 1957, was evidently due entirely to abnormal and easily avoidable conditions, and is without any bearing on the performance obtainable in future. The operating experience over some 2 years therefore offers good promise that germanium rectifiers will be thoroughly reliable in traction service.

Silicon Rectifier Unit

It was previously mentioned that monocrystalline rectifiers can also be made using other materials than germanium, the most promising of these other materials at present being silicon. The principle remains the same, namely a p-n junction formed inside a slice of single-crystal material of extremely high purity; but the manufacturing techniques are somewhat different, though analogous. Silicon rectifiers can operate at 60 to 120 deg C higher junction temperature than germanium rectifiers—a property which for some special applications is decisive, and they can be made for higher voltages per cell than germanium.

Both germanium rectifiers and silicon rectifiers have in different ways improved greatly during the past twelve months, and for most industrial and traction applications there is at present little, apart from the greater experience with germanium, to choose between their qualities, and it is likely that the choice between them will thus ultimately be governed mainly by cost. It is too early to attempt a cost comparison, since germanium cells are in large-scale production, with a high degree of uniformity, whereas this is as yet scarcely the case with silicon cells.

In these circumstances it seemed wise to proceed with a trial of a silicon rectifier, to gain experience with this also, as has been done with germanium. The manufacturer concerned therefore applied to the British Transport Commission to be allowed to install a silicon rectifier in place of the germanium rectifier in this motor coach, and this permission was granted.

The change consisted simply of replacing the trays of cells in the cubicle. The silicon cells are again forced-air-cooled, and are protected in the same way, but they are larger in size and rating and there are therefore fewer in series and parallel. There are in fact 32 silicon cells in series and 6 strings in parallel. Fig 5 shows one of the trays of silicon cells.

The change-over was made on June 12, 1958, without incident. However, because of trouble with other apparatus in this coach, not related

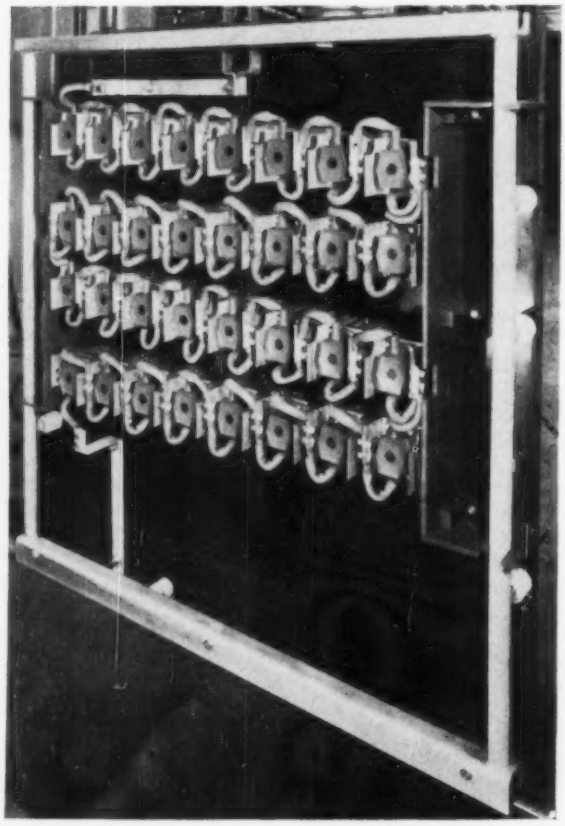


Fig 5. A silicon rectifier tray for the Lancaster–Morecambe–Heysham motor coach

to the rectifier equipment, regular commercial service did not begin until July 14, 1958.

The silicon rectifier has now been in service for about three months. During this time three of the silicon cells developed high resistance, which was found on investigation to have been caused in each case by a defective internal connexion in the cell. This fault occurred before the manufacturing techniques and testing had been fully established, and it has no bearing on the quality of the basic silicon units. The defective cells were each strapped across, thereby slightly increasing the stress on the remainder, and the equipment was put back into operation. Apart from these high resistance cells, no trouble or difficulty whatever has occurred and the equipment is still maintaining the normal service.

The period of operation has again included severe thunderstorms, and as silicon cells tend to be more sensitive to voltage surges than germanium, this experience affords reassuring evidence that adequate overvoltage protection has been devised.

In conclusion, the experience, limited though it is, is considered to afford grounds for the view that both germanium and silicon rectifiers have a part to play in ac traction equipments.

The authors wish to thank Mr S. B. Warder, the Chief Electrical Engineer of the British Transport Commission, and the Management of the BTH Co Ltd and the AEI Heavy Plant Division, respectively, for permission to publish the information contained in this article.

'Deuce' Computers for CEGB and AEA

THE Central Electricity Generating Board has recently installed an English Electric 'Deuce' computer at its headquarters at Bankside, London, SE1—the first installation of its kind to be operated by the electricity supply industry and the latest addition to an already extensive inventory of computing and control equipment.

The purpose of Deuce is, broadly, to assist in generating as economically as possible the steadily increasing power requirements of all types of consumers in this country by enabling the Board to make a rapid appraisal of alternative schemes of development five, six, and seven years ahead—a project which could not otherwise have been undertaken in the detailed form necessary to give accurate assessments in time to influence management decisions on future policy. In this way, said a CEGB spokesman, 'we have advanced still further the technique of forward economic planning which, having regard to the scale of the Board's operations, is believed to be in advance of anything of its kind in the world'.

On the occasion of a press visit to Bankside recently to see the new installation, Deuce was at work on an 'energy balance' calculation—that is, a problem simulating the conditions which will be presented to the national and area grid control centres in 1964, taking into account all the relevant factors such as increased load demand; availability of new generating capacity (nearly 10,000 MW additional, of which 1500 MW will be from nuclear plant); new grid transmission lines; availability, costs, and location of fuel supplies, and so on—all superimposed on the pattern of generation and transmission as it exists to-day.

This sort of calculation takes 'Deuce' about thirteen hours, whereas it would have taken something like six weeks of human calculation by an expert team, even using all the 'short cuts' possible.

The Deuce Mark I installed at Bankside is basically the same as the original machine but is fitted with a 64-column punched card reading and writing system (instead of the original 32-column system) and with facilities for magnetic tape auxiliary storage. The 64-column equipment is fully compatible with the extensive library of 32-column programmes and sub-routines which has been built up since the introduction of the computer and which is available to all Deuce users.

The computer has two types of storage: a high-speed store, immediately associated with the computing circuits, of the acoustic delay type using mercury delay lines and having a capacity of 402 words, and a large store of longer access time provided by a magnetic recording drum with a capacity of 8192 words. Punched card input and output rates are respectively 200 and 100 cards per minute.

The Industrial Group of the United Kingdom Atomic Energy Authority has also ordered a Deuce computer to be installed at the Group's diffusion plant at Capenhurst, near Chester. It is scheduled for delivery in March of next year.

The Capenhurst plant is concerned with the production of almost pure uranium 235 from uranium hexafluoride by the gaseous diffusion process, and Deuce will be used to study the performance of the plant. On the basis of the information fed to it on all aspects of production, the computer will be able to indicate optimum production schedules; it will also be used for research work in connexion with the plant.

This machine will be the Mark II version—basically similar to the CEGB's Mark I, but fitted with an 80-column combined input/output system. Provision is also made for adding magnetic tape equipment at a later stage, if required.

Notes

Two Big Submarine Cable Contracts for Britain

Two of the biggest submarine cable contracts ever placed in Britain have been obtained by *Standard Telephones & Cables Ltd*. They involve orders respectively for 530 nautical miles (970 km) of undersea cable and submerged repeaters for the Anglo-Swedish telephone cable project, and over 700 nautical miles (1279 km) of deep-sea cable, part of a new 36-channel telephone system to be installed next year between Miami, Florida, and San Juan, Puerto Rico. The values of these two orders are £1½ m and 2½ m dollars respectively.

The Anglo-Swedish project, which is a joint undertaking between the British Post Office and the Swedish Telecommunications Board, will provide the first direct telephone link between Britain and Sweden, and will require the longest European submarine telephone cable link yet installed.

The cable is a single core, shallow-water type of new design developed by STC in association with the British Post Office, and will provide 60 two-way telephone circuits. It will be manufactured in continuous lengths of approximately 18 nautical miles at the Southampton factory of STC, and the Post Office cable ship HMTS *Monarch*,* which is to lay the cable and repeaters, will berth near the factory and load the cable direct into her tanks via the loading gantry connecting the factory with the quayside. The total weight of the cable will be about 4800 tons.

The terminal equipment and submerged repeaters required for the system will be made at STC's North Woolwich factory. The terminal equipment provides the 120 carrier frequencies which enable 60 telephone lines to be worked simultaneously through the cable; it also provides electric power to operate the submerged repeaters. These are two-way amplifiers enclosed in pressure-resisting steel cylinders and spliced into the cable at intervals of about 18 nautical miles (33·4 km) along its length. STC pioneered the development of this type of rigid undersea repeater, a large number of which were laid between Nova Scotia and Newfoundland in the first transatlantic submarine telephone cable in 1956.*

The system is due to be brought into service round about October 1960.

The contract for the Puerto Rican project was placed by the American Telephone and Telegraph Company of New York.

The total route length of the link will be more than 1100 miles (1770 km), and the system will be similar to the first transatlantic telephone cable link. It will comprise two cables, each equipped with American-type flexible one-way repeaters for east and west transmission respectively. It will be owned jointly by the American Telephone and Telegraph Company and the International Telephone and Telegraph Corporation.

The cable, which will also be manufactured at STC's Southampton factory, will be laid in very deep water; off the north coast of Puerto Rico lies the Brownson Deep, which is more than 24,000 ft (7315 m) in depth. The completed cable weighs 3¼ tons per nautical mile (1780 kg per km), and will be manufactured in continuous repeater section lengths of about 38 nautical miles (70·5 km). After rigorous testing, the sections will be joined together by means of the flexible repeaters to be supplied by the Western Electric Company, New York.

Cable and repeaters, totalling about 2500 tons in weight, will also be laid by HMTS *Monarch* towards the end of 1959.

* THE BEAMA JOURNAL, **65**, No. 2, May 1958, p 55.

Activated Rudders on New Bowater Ships

The *Constance Bowater* is the second to be launched of the ships under contract with the Caledon Shipbuilding and Engineering Co Ltd of Dundee for the Bowater Steamship Co Ltd. These ships will carry pulp wood, baled pulp and newsprint, and a feature of their design is that they are fitted with a Pleuger 'Aktiv' rudder to give them increased manœuvring ability in confined waterways and dock entrances.

The principal characteristic of this device is an auxiliary propeller and an electric motor mounted as an integral part of the rudder, in order to provide steering torque even when the ship has little or no way on. The rudder motor is rated at 150 hp and is required for direct on-line starting, under which condition it takes three times the full load current.

The Pleuger 'Aktiv' rudder with an auxiliary propeller and electric motor which are mounted as an integral part of the rudder

To drive it, *Crompton Parkinson Ltd* supplied a motor alternator set comprising a light compound-wound 220 V dc motor directly coupled to a 3-phase 50 c/s 380 V alternator—both machines being mounted on a common bedplate. The alternator has an output of 142½ kW (190 kVA at 0·75 pf) at a full load speed of 1500 rpm, and although the inherent voltage regulation of the machine is good, an Isenthal voltage regulator has been supplied with the first equipment which gives regulation to ±2½ per cent from full load to no load.

This equipment was supplied in the first instance owing to the delivery conditions existing for the first vessel of the class; the remainder will have Crompton Parkinson self-regulating alternators of the 'Magnicon' type which have an inherent voltage regulation of ±2½ per cent. The machines supplied comply with Lloyd's requirements for machines for use in ocean-going vessels operating in tropical waters.

Crompton Parkinson Limited also supplied all the ancillary equipment on the *Elizabeth Bowater*, including the dc motor starter, the alternator switchboard, and the automatic voltage regulator.

Another British Computer goes Overseas

A high speed 'Mercury' digital computer made by *Ferranti Ltd* has been ordered by the Belgium Atomic Energy Authority—the seventh European Atomic Centre to adopt this computer. The others are Geneva, Paris, Oslo, Stockholm, and the United Kingdom Atomic Energy Authority's establishments at Harwell and Risley.

Complex mathematical calculations play a major part in all aspects of nuclear engineering, and 'Mercury', which was introduced some twelve months ago, has been specifically designed for large-scale scientific research work. It is claimed to be the most advanced computer in scope and speed yet produced in Western Europe and to put Britain among the leaders in electronic computer manufacture, because it can undertake large-scale research work which could previously be done only by a few very large computers in the USA.

The price of 'Mercury' is about £100,000 and so far 15 of them have been sold, five of which are going to the overseas destinations mentioned above.

Siemens Edison Swan Exhibition

Described by the firm as 'a modest exhibition of ourselves', this display staged by *Siemens Edison Swan Ltd* at their premises in Charing Cross Road, London, WC2, presents an epitome of the products of their seventeen product divisions and two subsidiary companies, and offers a wide range of interest to visitors.

Among the goods manufactured by the firm are cables of all kinds, electrical distribution material, public and private telephone systems, business communication devices, transmission systems, marine electrical apparatus, every type of lamp and lighting appliance, electronic control and indication equipment, batteries and accumulators, valves, transistors and cathode-ray tubes, radio components including those in PTFE and the like, wiring accessories, domestic appliances, plastic mouldings, etc.

From the many items in the exhibition which deserve special attention, one may perhaps refer to the latest development in telephones—the streamlined, light-weight '20th Century Neophone' which was the pioneer of printed circuit telephone hand-

sets; the historic lamp display with some of the original lamps made by Thomas Edison and Joseph Swan; the display featuring the first electrically operated train arrival indicator ever to be installed (it was at Paddington station, Great Western Railway, in 1934); and the comprehensive selection of compression and injection mouldings in all types of plastics including ptfe produced by Aldridge Plastics—one of the subsidiary companies which specializes in precision mouldings for the engineering industry. This company's capacity for the production of injection mouldings has lately been greatly increased to meet the demand for the new style GPO telephone handsets* which will shortly be going into production.

Cheaper than Collecting Rain

The Guernsey Water Board, in the Channel Islands, have made a decision which seems likely to become historic by ordering the first sea-water evaporating and distilling plant for commercial operation ever to be installed in a country with an adequate rainfall.

The reason for the apparent paradox is that the fruit and flower industries which are so important to Guernsey's economy depend vitally on plentiful fresh-water supplies, and the Guernsey authorities have found that it will prove cheaper to use the new Weir Multiflash plant than to build catchment areas and reservoirs to collect rain. The plant will produce 500,000 gallons (2273 kl) of fresh water daily from the sea, and the design of the Multiflash plant makes possible very high rates of fresh-water production per unit of heat input at a much lower capital cost than has previously been possible.

The Guernsey installation will be supplied by *G. & J. Weir Ltd* of Glasgow, who have already supplied the plant which produces three-quarters of the world's total output of fresh water from the sea. It will take the form of a fabricated mild steel structure, 70 ft (21 m) long, 19 ft (5·8 m) wide, and 19 ft (5·8 m) high, internally divided into various 'flash' and preheater sections. A deaerator unit will reduce to a minimum the causes of corrosion by removing gases dissolved in the incoming sea-water, and chemical treatment of the sea-water will prevent scale formation on the internal surfaces of the plant to allow continuous operation at maximum output.

It will be completed and commissioned early in 1960.

Birlec Expansion Overseas

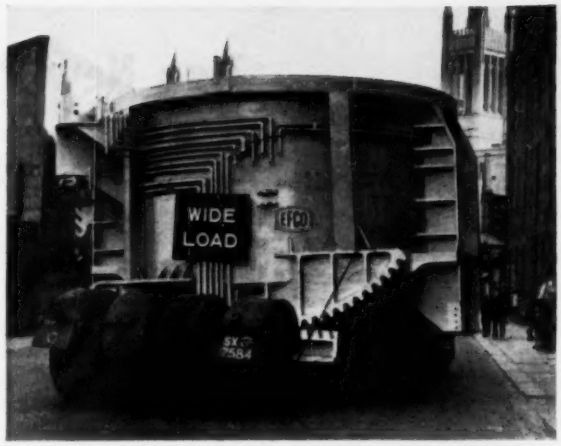
Birlec Ltd of Birmingham have recently announced the formation of a new branch in Johannesburg, South Africa. Situated between Boksburg and Benoni, the new branch (postal address PO Box 99, Witfield, Transvaal) will deal with all inquiries including project design and engineering service work.

Some three years ago Mr S. G. King—formerly manager of Birlec's London office—established an office in Johannesburg, where he acted in advisory capacity to the BTH Company (SA) Pty Ltd who, for the interim period, were agents on behalf of Birlec. During the last two years excellent progress has been reported, culminating in several major orders including a 10-ton arc melting furnace for Scaw Metals Limited.

It is expected that the chief demand will be for melting furnaces, particularly for those used mainly in making alloy steels. While certain special equipment and parts will continue to be imported from the main Birmingham works, the majority of the equipment will be manufactured locally by the Firlst Electro Corporation.

In the Federation of Rhodesia and Nyasaland the British Thomson-Houston Company (Central Africa) (Pvt) Limited will continue to act as Birlec agents, but the services of the new branch will now be fully available to Birlec furnace users in the Federation, particularly for technical advice and assistance when required.

This development is a continuation of Birlec's policy of expansion into overseas markets, and comes only some six months after the announcement that a Canadian branch office has been established in Toronto.



The body of an electric steel melting furnace on the first part of its journey to Canada. Weighing approximately 100 tons, it was made by Efco (Electric Furnace Co Ltd) of Weybridge, Surrey, and is destined for Vancouver, BC. This photograph shows it on the way to Aberdeen Docks for shipment

British Oil Refinery Equipment for Brazil

A British consortium of oil equipment manufacturers has now received a contractual letter of intent from Petrobras (the Brazilian Government oil monopoly) covering the purchase of a minimum of £4 m worth of equipment for a new refinery to be constructed near Rio de Janeiro. This satisfactory outcome of negotiations during a visit to Brazil by members of the consortium was secured in the face of French, German, and Italian competition.

Petrobras has retained Foster Wheeler's for the design, engineering, and supervision of the refinery; the consortium—which was formed through the aegis of the Council of British Manufacturers of Petroleum Equipment—include the principal UK manufacturers of oil refinery equipment and allied products. Known as the British Refinery Constructors ('Brefcon'), it is headed by *Babcock & Wilcox Ltd, The British Thomson-Houston Co Ltd, Stewarts & Lloyds Ltd* and John Thompson Ltd; Balfour, Beatty & Co Ltd are acting in a secretarial and coordinating capacity.

New Exide Factory in Central Africa

A new factory to produce Exide automotive batteries has recently been opened in Salisbury, Southern Rhodesia. It has been built by *The Chloride Electrical Storage (CA) (Pvt) Co Ltd*, and its products will be marketed in the Federation of Rhodesia and Nyasaland.

The plant covers an area of more than 20,000 sq ft (1858 m²) and is equipped with the latest type of machinery and moulds designed by the Plant Development department of the parent company in Manchester for the particular conditions prevailing in Rhodesia. Both European and African staff are employed, and men handling lead in any form are regularly examined by the Company's medical officer, who works in close collaboration with the Chloride medical staff in England, under the supervision of Professor Lane at Manchester University.

The African plant contains extensive servicing facilities, not only for users of Exide automotive batteries, but for all Chloride products, such as traction batteries used in the mines, stationary batteries in power stations, and batteries for the railways.

'Installation and Care of Electrical Motors and Control Gear'

This is the title of an 82-page pocket-size booklet produced by *The British Thomson-Houston Co Ltd*. This latest edition is a revised and enlarged version of the first edition published in 1953 and for which there has been a widespread demand.

The introduction contains useful information on choosing a motor, and the subsequent eleven chapters consist of notes on installation, care, and maintenance, diagnosis of faults, and causes and effects of unsatisfactory performance. A chapter is devoted to control gear, and includes hints on the installation and maintenance of various types of equipment.

The text is adequately supported by diagrams, graphs, and photographs, and concludes with a useful collection of miscellaneous data. The booklet stresses the importance of efficient and regular maintenance in reducing the risk of breakdown and helping to ensure continuity of production, and it should be of immediate practical assistance to maintenance staffs.

Copies are available to anyone professionally interested on application to the BTH Publicity Department, Rugby, Staffs.

[*Continued on page 172*

* THE BEAMA JOURNAL, **64**, No 2, May 1957, p 52.

Two New Power Stations

FORMAL opening ceremonies were held during September and October at two of the newest generating stations of the Central Electricity Generating Board—South Denes, on the Norfolk coast near Great Yarmouth, and Castle Donington, on the River Trent in Leicestershire. Both stations have many features of special interest.

South Denes

South Denes, operated by the Board's Eastern Division, will have an installed capacity of 240 MW. The first two of the four 60 MW units have now been commissioned; the other two are scheduled for completion by January 1960.

Designed initially for coal burning, plans had to be altered when it was decided in 1955 to convert the plant for oil burning, using residual oil as a fuel. This involved many design problems which were ultimately solved with the minimum of boiler-efficiency loss; in fact, at the acceptance tests, the boiler efficiency was 87·5 per cent and the overall station efficiency 29·7 per cent.

Each of the boilers is arranged to be connected as a unit to one turbine. The two units now in service were originally designed for coal, and each has 28 remotely controlled oil burners—7 in each corner of the combustion chamber; automatic steam temperature control is obtained by tilting the burners and by spray-type de-superheaters. The two new units will be of more conventional design with 12 oil burners in the front wall of the combustion chamber, and automatic steam temperature control by spray-type de-superheaters only.

The boilers are rated at 550,000 lb (250,000 kg) per hour, with steam conditions at the stop valve of 950 lb/in² (66·8 kg/cm²) and 910 deg F (488 deg C).

The two 60 MW turbogenerators now in service are 3000 rpm two-cylinder units of the impulse type with the low pressure side exhausting at 28·9 in (735 mm) vacuum to twin condensers. The steam conditions are 900 lb/in² (63 kg/cm²) at 900 deg F (482 deg C). The turbines are coupled to 15 lb/in² (105 g/cm²) hydrogen-cooled generators which operate at 11·8 kV, 0·8 power factor, and are directly connected to the generator transformers. The units still under construction are also 60 MW two-cylinder units running at 3000 rpm but are of the combined impulse and reaction type, with multi-flow single exhaust low pressure turbines exhausting at 28·9 in (735 mm) vacuum to single shell condensers.

Fuel oil is delivered by ocean-going tankers to three storage tanks with an ultimate capacity of 38,500 tons, and pumped to the boiler burners at a final pressure of 600 lb/in² (42 kg/cm²) and a temperature of 280 deg F (138 deg C). The oil heating system is by hot water at 250 lb/in² (17·6 kg/cm²) and 400 deg F (204 deg C) from three automatically operated auxiliary boilers, and the pipe-lines and storage tanks are also maintained at a suitable temperature for the circulation of the oil.

One of the notable features of South Denes is the provision of complete remote control of the station from the operating room, including starting up, electrical loading, and 'on load' control of the boiler/turbine units. Miniature-type instruments and controls are used throughout, and all controls and indications are transmitted either electrically or pneumatically; there are no steam or water connexions to the control room.

The station is also one of the first CEGB plants to use sea water, and twin sea water evaporators have been installed for each of the two units now in service and will also be installed for No 3 unit, delivering distillate to a water-treatment plant designed to produce 16,800 gals (76,372 l) per hour of completely treated water.

Electricity from the two units now in service is supplied to the 33 kV distribution system, while that from Nos 3 and 4 units will be supplied direct to the 132 kV grid.

Castle Donington

This station is a notable outcome of the forward thinking which, in 1950, dictated a major break away from previous standard practice and laid plans for an installed capacity of 600 MW from six units, each of 100 MW rating, with steam conditions at the turbine stop valve of 1500 lb/in² (105·5 kg/cm²) and 1050 deg F (571 deg C).* Each turboalternator was to be associated with a single boiler with a steam rating of 830,000 lb (376,482 kg) per hour, and the boilers which have now been commissioned at Castle Donington are, in fact, the largest in Europe.

The East Midlands Division of the CEGB was able to claim for this station† the highest thermal efficiency of any of the Board's conventional stations with a figure of 32·16 per cent—over 1 per cent higher than the next best, giving a fuel consumption of 1·093 lb (496 g) per hour for each unit sent out.

Five of the six 100 MW units have now been commissioned, and the sixth is planned for operation during next summer. The turboalternators run at 3000 rpm; the turbines are of the two cylinder impulse type with double flow low pressure cylinder, and the steam is exhausted into twin two-pass condensers with a total cooling surface of 80,000 ft² (7430 m²), requiring 64,000 gals (291,001 l) per minute of cooling water.

The first three alternators have a generating voltage of 13·8 kV and a rating of 100 MW at 0·8 power factor when operating at a hydrogen pressure of 0·5 lb/in² (35 g/cm²) above atmosphere. They are directly connected by 120 MVA 13·8/145 kV transformers to the 132 kV switchgear, and are switched and synchronized at that voltage.

Direct 275 kV Switching

The second three alternators also generate at 13·8 kV at a rating of 100 MW at 0·9 power factor at a similar hydrogen pressure. Nos 4 and 5 are, however, the first machines in the country to be connected by 106 MVA 13·8/295 kV transformers to the 275 kV switchgear of the Super Grid, and No 6 will be similarly connected.

There are two main outdoor switching stations—one for 132 kVA switching, equipped with twenty 3500 MVA oil circuit-breakers for control of three of the 100 MW generators; two 275/132 kV 120 MVA auto-transformers, and two banks of 132/3·3 kV station transformers. In the 275 kV switching station there will be three 7500 MVA bulk oil circuit-breakers for direct switching of the other three generators.

* THE BEAMA JOURNAL, January 1953, p 29.

† Annual Report of the Electricity Council, March 31, 1958.

Large Power Transformers

E. T. Norris, MIEE, MIMechE, Fellow AIEE*

A NOTABLE feature of the progress in electricity supply over the last sixty years has been the continued growth in the size of power transformers. This growth has shown no signs of saturation and indeed has been accentuated during the last few years.

Over thirty years ago transformers of 100 MVA and 100 kV had been built. At the present time the rating has increased to over 400 MVA and the voltage to 400 kV or more. A three-phase unit has been built in this country for 345 MVA at 165 kV. It may be noted that the increase in MVA rating has run roughly parallel with the increase in line voltage so that, over the years, the current rating of the high-voltage winding has not changed. This follows from the fact that overhead transmission lines have not altered appreciably in current carrying capacity over the last fifty years. On the other hand, the maximum current rating of the low-voltage windings has increased four-fold, since generation voltages have remained virtually constant.

The modern practice of superimposing higher voltage systems on existing networks has increased the use of auto-transformers for interlinkage, especially for 132/275 kV and 275/400 kV combinations.[2] It is now the usual practice to choose three-phase units wherever transport conditions permit, if necessary using five-leg three-phase cores. For the 400 kV range, however, single-phase units become usual, and here the overall height can be reduced by means of four-leg cores.

Apart from the obvious requirements of rating and voltage, there are other external factors restricting the design and construction of large transformers, especially for export. The over-riding restriction is, in general, transport conditions, both as regards the maximum weight of a single unit and dimensional limitations such as railway loading gauges, bridge clearances, etc. These restrictions will generally determine whether three-phase units are possible or whether banks of single-phase units must be chosen. It may even be necessary to split either of these alternatives into two or more transformers in parallel.

Other external factors include the reactance, which may be limited in either an upper or lower direction by voltage regulation, system stability, or short-circuit current limitations. This latter can be a serious consideration for large capacity systems where short-circuit ratings of 25,000 MVA are now possible.

At the generation end, since water turbines are limited to about 150 MW capacity, it is common to have two alternators feeding one transformer. On the other hand, with steam generation there is no such limit to the turbine capacity and it may even happen that the reverse condition occurs, one alternator supplying two transformers.

One more external factor is the specified insulation level to meet any particular lightning and switching surge stresses. This will depend upon the system lay-out, the severity of lightning, and the method of protection.

The effect of size may be shown by treating design as a three-fold combination of electrical, mechanical, and thermal considerations. For very small transformers only electrical stresses are concerned. As the size increases heat dissipation becomes a problem, *i.e.* thermal stresses need individual consideration. For the largest transformers, while both electrical and thermal stresses are accentuated, mechanical stresses become rapidly more prominent and in many cases can be an over-riding consideration. This three-fold combination in an intense form, together with the external controls previously mentioned, make the design and construction of very large transformers an intricate and complicated matter.

Throughout the history of transformer construction there have been two basic types known as core and shell. The orthodox definition of these types is that in the former the coils surround the core and in the latter the

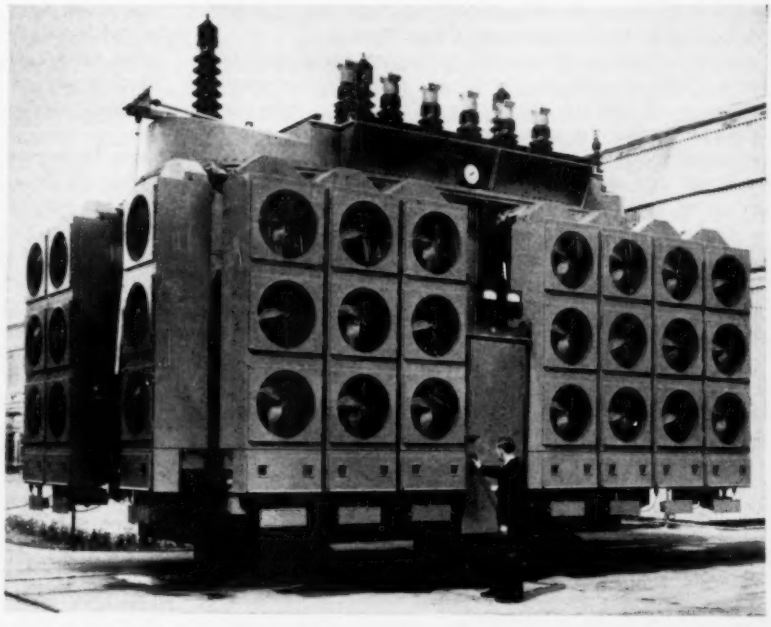


Fig 1. 345 MVA 161/22·5 kV 3-phase 60 cps transformer with air-blast cooling and forced oil circulation, total weight 237 tons, for the Tennessee Valley Authority, USA. (The English Electric Co Ltd)

* Consulting Engineer, Ferranti Ltd.

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Apart from the obvious requirements of rating and voltage, there are other external factors restricting the design and construction of large transformers, especially for export. The over-riding restriction is, in general, transport conditions, both as regards the maximum weight of a single unit and dimensional limitations such as railway loading gauges, bridge clearances, etc. These restrictions will generally determine whether three-phase units are possible or whether banks of single-phase units must be chosen. It may even be necessary to split either of these alternatives into two or more transformers in parallel.

Other external factors include the reactance, which may be limited in either an upper or lower direction by voltage regulation, system stability, or short-circuit current limitations. This latter can be a serious consideration for large capacity systems where short-circuit ratings of 25,000 MVA are now possible.

At the generation end, since water turbines are limited to about 150 MW capacity, it is common to have two alternators feeding one transformer. On the other hand, with steam generation there is no such limit to the turbine capacity and it may even happen that the reverse condition occurs, one alternator supplying two transformers.

One more external factor is the specified insulation level to meet any particular lightning and switching surge stresses. This will depend upon the system lay-out, the severity of lightning, and the method of protection.

The effect of size may be shown by treating design as a three-fold combination of electrical, mechanical, and thermal considerations. For very small transformers only electrical stresses are concerned. As the size increases heat dissipation becomes a problem, *i.e.* thermal stresses need individual consideration. For the largest transformers, while both electrical and thermal stresses are accentuated, mechanical stresses become rapidly more prominent and in many cases can be an over-riding consideration. This three-fold combination in an intense form, together with the external controls previously mentioned, make the design and construction of very large transformers an intricate and complicated matter.

Throughout the history of transformer construction there have been two basic types known as core and shell. The orthodox definition of these types is that in the former the coils surround the core and in the latter the

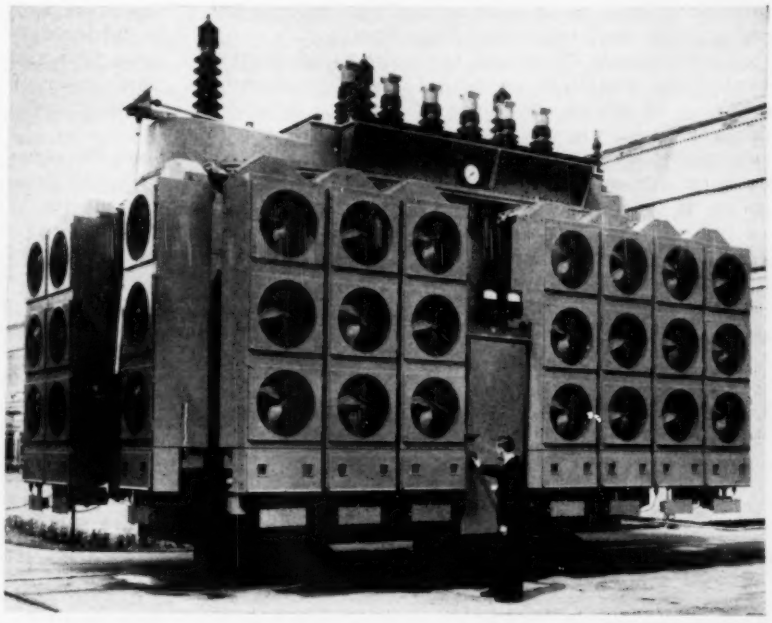

Fig 1. 345 MVA 161/22·5 kV 3-phase 60 cps transformer with air-blast cooling and forced oil circulation, total weight 237 tons, for the Tennessee Valley Authority, USA. (The English Electric Co Ltd)

* Consulting Engineer, Ferranti Ltd.

core surrounds the coils. A more practical distinction is that in core type transformers, the windings are usually cylindrical in shape and concentric in assembly; whilst in the shell type, they are rectangular in shape and interleaved or sandwiched in assembly. Although the majority of manufacturers adopt the core construction, both types are still made, even for the largest sizes, and are apparently competitive. Since the iron core or earth part of the structure surrounds the core in the shell type, the tank can fit closely round the sides but needs full insulation clearances at the top and bottom. With the core construction, the tank can fit closely to the core at the top and bottom but needs clearance to the windings at the sides. In consequence, shell type transformers tend to be smaller in plan dimension but greater in height than the core type. The fact that all British transformer makers adopt the core construction may be due to the relatively restricted loading gauge in most countries except Central Europe and North America and, in particular, to the limitation in height for transport which handicaps the shell type.

Grain-oriented Steel

Perhaps the greatest contribution in recent years to progress in transformer construction has been the development of cold-rolled, grain-oriented electrical sheet steel.[3] This steel is now in large-scale commercial production and is rapidly supplanting the older hot-rolled material. For a given flux density its loss is less than half that of hot-rolled steel. Considerably higher flux densities can thus be employed and still result in a notable loss reduction. The upper limit is set by harmonics and inrush magnetizing current, since the saturation flux density is not appreciably increased.

While the grain-oriented steel is being used in all classes and sizes of transformers with reductions in weight and size and in both iron and copper losses, it is particularly valuable for large power transformers in easing transport limitations in both weight and dimensions.

In order to make the best use of the directional qualities due to grain-orientation, stress-relief annealing is essential following all cutting operations. Continuous annealing furnaces are now in use giving more uniform treatment and continuous production. The principles of core construction and assembly are being studied *ab initio* to realize as fully as may be the possibilities of the new material, and various forms of interleaved and mitred jointing have been considered.

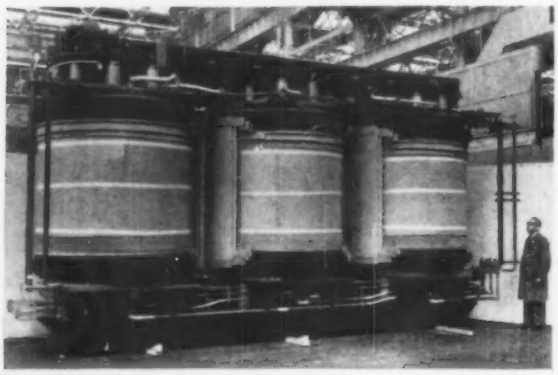

Fig 2. 60 MVA 330/88 kV 3-phase 50 cps transformer, Type ON/OFB, with automatic on-load tap-changing gear, for the Kariba hydro-electric scheme on the Zambesi River, Rhodesia (Ferranti Ltd)

Winding construction may be divided broadly into three simple types,[1] of which two will be used in any one design. The lower voltage heavy current windings are generally of the helical single layer construction with many strands in parallel, suitably transposed to reduce eddy current and circulating current losses. Until recent years the higher voltage windings were generally made up of a large number of disc sections either wound in pairs and connected in series, or, more lately, wound continuously with no joints. An alternative type is a multi-layer construction consisting of a number of successively shorter layers assembled concentrically over the LV windings. This is particularly suitable where one end of the winding is earthed and the insulation can be graded through the successive layers to the high-voltage terminal. The type is not new, as it has been employed for many years in the construction of high-voltage testing transformers where only electrical stresses need consideration. In this respect, the multi-layer winding is advantageous both as regards power frequency and surge stresses. It is not quite so attractive from the point of view of thermal and mechanical stresses. In consequence, both types of winding are employed even by the same manufacturer, depending upon the individual manufacturing technique and design practice.

The winding insulation nowadays consists almost entirely of oil-impregnated paper and press-board in various forms. The conductor insulation is invariably paper wrapping. The combination of paper and oil has a relatively high electric strength, but has the disadvantage that it is susceptible to moisture absorption, since fibrous insulation has a greater affinity for water than transformer oil.

The oil impregnation of the insulation is done after the windings have been completed and assembled. A high degree of vacuum is required and the process may be carried out either in a separate vacuum chamber or when the transformer is finally installed in its own tank which must, of course, be constructed to withstand the resulting mechanical stresses.

Some Necessary Precautions

Although paper and press-board is an excellent insulation and very convenient to use, it has the disadvantages, in common with all fibrous materials, of being not only electrically but mechanically affected by moisture absorption, and, in addition, of having non-linear mechanical properties. In consequence, great care and precautions are necessary to ensure that the windings are mechanically rigid and electromagnetically balanced, not only in the design stage but after the mechanical strains in the insulation due to the assembly and impregnation processes have been stabilized.[3]

It is becoming usual in the larger transformers for tapping sections to be separate layer windings or coils so that the mechanical strength is not appreciably affected by the particular tapping in use.

The cumulative effects of repeated short-circuits are being studied, both with regard to tensile stresses in the conductor and compressive stresses in the insulation.[7] It is clear that the mechanical strength of a transformer is not a single value as has been generally assumed; some strains are progressive and some of the stresses cumulative, leading to short- and long-term characteristics.

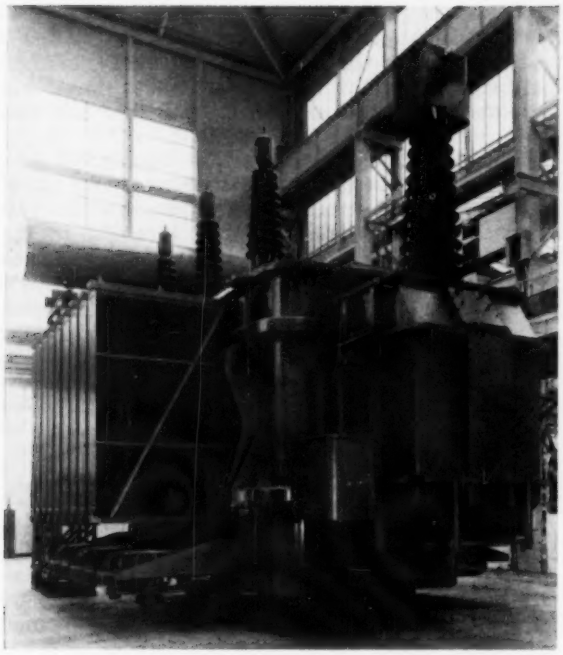

Fig 3. 75/48·75 MVA, 150/26·25/10·5 kV 3-phase 50 cps transformer, Type ON/OB, with on-load tap-changing gear, for South Holland Marconistraat Substation (Metropolitan-Vickers Electrical Co Ltd)

While mechanical stresses increase, in general, with the transformer rating, the severity of short-circuits is increasing due to larger system capacities. The short-circuit current permitted by system planning engineers is generally based on the rupturing capacity of circuit-breakers, and this has increased in twenty-five years from 1500 MVA to 20,000 MVA or more. The dependence upon number or frequency of faults is, however, the more serious because there is a tendency for these to increase due to the practice of auto-reclosing, which makes the repeated switching on to possible faults a normal practice; the introduction of fault-throwing for inter-tripping purposes where dead short-circuits are deliberately created under normally controlled conditions; and the more recent adoption of line-ground switching. For all these reasons there is a general awareness, in recent years, that mechanical strength has become a matter serious enough for individual consideration in conjunction with system short-circuit conditions.

Progress in Fault Detection

For the high-voltage windings the intercoil and interturn insulation must be designed to meet not only the normal power frequency stresses, which is comparatively easy, but also the stress distribution due to lightning and switching surges. It is now possible to design windings to have any desired value of surge strength, whether resulting from incoming travelling waves, waves chopped by flashover in the station, or switching surges.

Until recently, it was widely felt that there was some danger in subjecting a transformer to surge tests of any kind, on the grounds that some partial damage might be done which would not be detected and might result in a weakened transformer going into service. The technique of fault detection has, however, made such progress within the last few years that this fear may now be considered groundless. Indeed it may well be claimed that the risk is even less than for similar undetected damage due to the familiar power frequency pressure and over-potential tests. The most important development in recent years has been the technique of obtaining chopped waves with precise timing, which enables such exact repeatability of applied surges that the neutral current method of fault detection can be applied to chopped waves as well as full waves.[4] Hitherto, reliance has had to be placed largely upon repeating a full wave test after the chopped wave, which is an uncertain means of detection. It is now possible to determine with assurance any failure or partial failure in the insulation, due either to full or chopped waves.

Because of this assurance it is now becoming universal practice to insist (as has been usual in British and American Specifications) upon the application of both chopped- and full-wave impulses, since the former represent a practical operating condition giving the most severe stresses in the winding insulation. With the realization that impulse stresses are now under full technical control there has been a trend towards reducing the test values by lowering the basic impulse levels as standardized in national specifications by one, or even two, steps.

The standard impulse tests demonstrate that the transformer insulation is equal to, or greater than, the surge test level. They ensure that the transformer has this minimum surge strength, but that does not guarantee that it is lightning proof. It is a separate problem for the user to provide such external protection as will limit the incoming surge to a suitable value (at least 20 per cent is suggested) below the test level, dependent upon the severity of operating conditions and the margin of safety required.

The Value of Computers

The complication of large transformer design in meeting the numerous mechanical, electrical, and thermal stresses under normal and abnormal operating conditions as well as on test is being eased by the application of digital computers.[6] The fundamental design work consisting of the choice of materials, the limiting values of stresses, and the methods of calculation can only be done by skilled designers. There remains, however, in every individual design, the numerical calculation of all the technical characteristics, the process being repeated by trial and error ('iterations' is the modern term) until a combination has been reached which satisfies the specification requirements while meeting all the stress limitations. While this work is purely arithmetical and could be done by junior or even non-technical assistants, the number of iterations for the most economical design would be beyond the limits of human fatigue.[3] The digital computer knows no such limits and is mathematically accurate in its calculations, however numerous and complicated. It thus saves the designer much mental drudgery and can also be used for incidental work of a laborious nature such as the precise calculation of reactance, eddy-current losses, surge stresses, mechanical forces, and thermal characteristics. As may be expected, considerable reorganization of design procedure is necessary in adapting design calculations to computer techniques and in programming the information fed into the computer in a form assimilable by it.

Transformer noise[5] is, in general, most objectionable

to near-by residents. Large power transformers are usually installed in correspondingly large generating or sub-stations where the distance to the nearest resident is comparatively great. Nevertheless this distance is frequently small enough for the noise to be admittedly objectionable.

While the noise can obviously be reduced by lowering the flux density, this is not in itself an economical solution and is generally abandoned. Magnetostriction and transverse vibrations of the laminations are the major causes of noise. The former is an inherent characteristic of the core material, while the latter, assuming correct design of the clamping and core section, is thought to be caused largely by waviness of the sheets and by cross fluxes between the laminations due to large variations in the permeability of different sheets and even in different parts of the same sheet. Limited noise reductions have been achieved by intensive study of these features.

Fig 4. 120 MVA 275/66 kV 3-phase 50 cps transformer for the Central Electricity Generating Board, in transit by road (C. A. Parsons & Co Ltd)

The only remaining solution is to shield the transformer itself by walls, sound enclosures, or buildings. Noise reductions up to 30 db can be obtained in this way. An economical solution suitable for transformers with separate cooling banks (an arrangement which has been British standard practice for many years) which avoids the cost of a complete building is a weather-proof blanket for the transformer, the bushings being allowed to protrude. On installation the foundations are made suitable for this enclosure, which then needs to be erected only if and when noise is objectionable. Air-blast fans cooling the radiator bank are of course outside the enclosure and their noise is not reduced, but in most cases they will not be in operation during the night when noise is most objectionable.

Cooling Methods

Some form of forced cooling is either essential or at least economically attractive for all large power transformers. In generating stations, especially hydro-electric where water is available, water cooling with separate heat exchangers and forced-oil circulation is the most economical.

In all other cases air cooling radiators with forced fan or blower cooling and forced-oil circulation are usual. The degree of cooling can be thermostatically controlled in two or more stages by suitable operation of fans and pumps. Forced-oil circulation, which has been British practice for thirty years, has recently become almost universal. The oil pumps with their motors are completely submerged in the oil so that oil-tight glands are eliminated and no oiling or greasing is required. Wear is negligible, the power absorbed is small and operation practically noiseless. For these reasons there is now a tendency to leave the oil pumps running continuously for the benefit of the lower winding temperature and correspondingly reduced winding resistance and load loss.

On-load tap-changing gear or load ratio control is, in British practice, an established standard fitment for all large power transformers. In recent years there has been a pronounced trend towards resistor- instead of reactor-type switching. While each type can be designed quite satisfactorily for any given service, the resistor type is more suitable for high-voltage operation and the switching duties are easier. Transfer switches with high-speed spring operation giving arcing times within one half-cycle have been developed with correspondingly reduced burning of contacts. Contact lives have been increased from tens of thousands into the region of hundreds of thousands of operations.

Tap-changer Design Developments

For the high-voltage auto-transformers referred to earlier in this article the usual connexion of on-load tap-changing gear at the transformer neutral point is relatively inefficient even for earthed neutral systems. For an auto-transformer of 2 : 1 ratio, for example, the necessary tapping range would be doubled. An important British development during the last few years has been the design of tap-changers insulated for direct connexion at the live terminal of the lower voltage system. A typical example is the use of tap-changers at the 132 kV live point of the 120 MVA 300/145 kV auto-transformers installed in the British Supergrid system. The whole of the switching gear and tapping connexions withstand the full impulse tests with chopped and full waves for the 145 kV system.[1], [2]

The acceptance of on-load tap-changing as a normal feature of transmission and substation transformers has

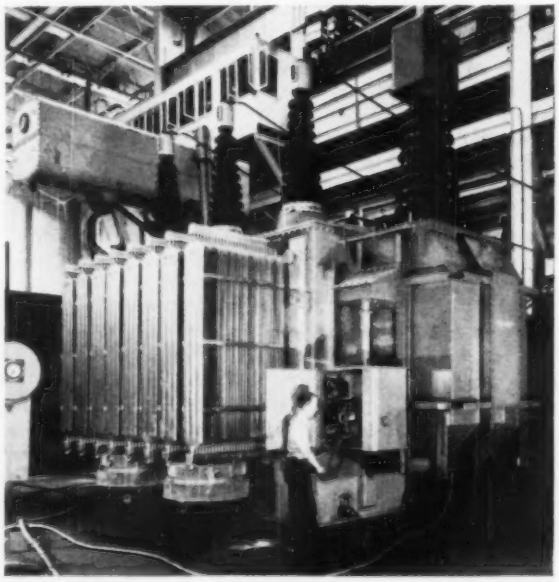

Fig 5. 40 MVA 115/34·5/11 kV 3-phase 60 cps transformer, Type ON/OB, with on-load tap-changing gear, for Venezuela (The British Thomson-Houston Co Ltd)

led in recent years to its adoption in generator transformers (*i.e.* transformers forming a unit with their associated generators) in order to relieve the generator and exciter of voltage control duty. For this application the range of voltage control is usually less, and the number of tappings fewer, than for transmission transformers.

The larger the transformer and the higher its voltage, the more vital becomes the maintenance and preservation of the oil in service. Recent developments have been in the direction of protecting the oil from exposure to oxygen or air and from the entry of moisture. Oil conservators and dehydrating breathers have long been the usual practice and are well established. There are now numerous alternatives, such as filling the space above the oil with nitrogen; providing a cushion of nitrogen either in the main tank or in separate expansion vessels sufficiently large for hermetic sealing; controlling the nitrogen pressure by automatic regulators; and finally by means of a plastic or flexible bellows to take up changes in volume while hermetically sealed. The last method is, of course, an obvious solution of the problem and depends entirely upon the assurance of a flexible or plastic material which will withstand the hottest oil temperatures over many years and the continual flexing in service without losing its elasticity or oil-tightness. It must also be proof against faults and abnormal operation conditions.

Most of these alternative methods of sealing are more expensive and complicated and need more maintenance, and some of them have since been abandoned for other reasons. Although in theory their advantages are plausible, yet operating experience the world over has shown that the simple conservator and breather has given complete protection to the oil under all normal and abnormal conditions. A recent examination in the United States of a large number of transformers in service, of all ages and selected at random, has shown negligible signs of progressive deterioration over many years.

Some of the alternative oil protection systems just mentioned are not suitable for the Buchholz or gas-detecting relay which has now become generally established as a warning of incipient faults and as a back-up to the normal electromagnetic protective systems. The advantages of the warning due to an incipient fault may be overestimated, since the faulty condition may be only temporary and, even if sustained, may not justify taking the transformer out of service immediately.

Practical experience shows that successful and effective operation of the relay depends not so much upon its normal indications as upon their interpretation. Gas indication should be regarded as a *prima facie* case for investigation. This applies to both gas leakage and pressure indications, although with the latter there are usually other and obvious symptoms which leave no room for doubt.

The over-riding effect of transport limitations on the design and construction of large high-voltage power transformers has already been mentioned. The restrictions are obviously peculiar to individual site and transport conditions and cannot be generalized. They include rail and road loading gauge limits, truck capacities, bridge clearances or bridge loadings. Where possible the transformer is despatched completely installed in its own tank and filled with oil. This of course is only possible for the smaller sizes. Where oil filling is not possible, owing to weight or transport conditions, the tank is filled with gas under a slight pressure. On arrival on site the pressure is checked and oil filling may then be commenced without any need for drying out treatment. In some cases it is economically feasible to build the tank partly or wholly of aluminium alloy in order to bring the total weight within transport restrictions. Beyond this limit the transformer and tank are shipped separately, the former usually in a light sealed casing for preservation during transport. Additional help can be obtained by removal of on-load tap-changing gear compartments, bushing pockets, and all cooling fittings.

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Sea Trials for the Cross-Channel Power Cable

THE project to link the electricity supply systems of Britain and France by an underwater cable* was brought a stage nearer fulfilment when a sea trials programme was carried out in mid-Channel during September and October.

It will be recalled that the British and French electricity authorities—the Central Electricity Generating Board and Electricité de France—have decided to use high voltage dc transmission instead of an ac link. This has the advantages, among others, of requiring only two submarine cables instead of four and of providing an asynchronous connexion so that the frequencies of the two grid systems can be regulated independently.

The cables which are finally to be laid will be some 30

The MV 'Dame Caroline Haslett' taking on board the special gear for simultaneous laying of the two cross-Channel cables

miles (48 km) long between the English coast near Dungeness and the French coast just south of Boulogne, and will lie at a maximum depth of 200 ft (61 m). Half the cable will be made and laid by British manufacturers and the other half by French manufacturers, and the two halves will be joined at approximately mid-Channel.

British Insulated Callender's Cables Ltd and Siemens Edison Swan Ltd have been commissioned to undertake the work jointly for the CEGB, and for the sea trials each company manufactured one 880 yard (805 m) and one 200 yard (183 m) length of cable. They were made to slightly different designs in order to provide data which will help to determine the final design of the cable and accessories. The cable conductor is 0·525 in² (339 mm²), with impregnated paper, solid type dielectric to operate at 100 kV dc conductor-to-earth. The insulated core is lead sheathed, the lead being protected from chemical action by an impervious covering and from mechanical damage by heavy galvanized steel wires, with an overall covering of impregnated jute. The external diameter of the cable is 3·07 in (7·8 cm) and the weight 36 lb per yard (14·5 kg per metre).

As the cross-Channel link will consist of two single-core cables carrying up to 800 A go-and-return, at a conductor-to-conductor voltage of 200 kV dc, the presence of two such cables on the sea bed would give rise to significant interference with ships' compasses if they were laid more than a few feet apart.

One of the main purposes of the sea trials was, therefore, to confirm the technique of laying simultaneously two cables in a depth of 18-19 fathoms (33-35 m) at equal tension and separated by not more than 10 ft (3·05 m). Other purposes were to confirm the practical technique for repairing the cables by the jointing-in of new lengths and to obtain as much information as possible from electrical and physical tests during the trials, and afterwards in the firms' laboratories.

The trials programme consisted of the simultaneous laying of the two 880 yard (805 m) lengths of cable at not more than the required 10 ft (3·05 m) apart. The cables were then severed by an explosive charge; the ends on each side of the fracture were brought to the surface and the cable repaired by jointing in the two 200 yard (183 m) lengths. The distant ends of the original cable were then jointed together to form a loop for electrical continuity and resistance tests at ± 300 kV. The whole of the cable was then recovered for critical tests and physical examination in the laboratories.

Considerable use was made of underwater ciné and still photography, and in this work and for the placing of the explosive charges, the British firms had the cooperation of a midget submarine supplied by the Compagnie pour l'Exploitation Internationale des Procédés Rebikoff, and skin divers of the Société Générale de Travaux Maritimes et Fluviaux.

The ship selected for the trials was the MV *Dame Caroline Haslett*, a 2700-ton collier owned by the CEGB and specially modified and equipped with cable-laying and handling gear designed to ensure exactly simultaneous and even laying of the two cables.

It is hoped to lay the permanent cables during the summer of 1960 and to have the cross-Channel link available for load during the winter of 1960/61, giving an interchange of 160 MW between the British and French grid systems.

* THE BEAMA JOURNAL, November 1956, p 156; November 1957, p 175.

New equipment and processes

280 W Integral Sodium Lamp

Introduced last month by *The General Electric Co Ltd*, the new Osram integral sodium lamp rated at 280 W has a light output of 16,800 lumens, which is comparable with that of the 400 W mercury lamp and represents some 85 per cent more light than the 140 W sodium lamp with a separate jacket.

The integral jacket has the same dimensions as the previous Osram 140 W integral lamp, but houses two arc tubes rated at 140 W each. Efficiency is given as 60 lumens/watt throughout an average life of 4000 hours. Each arc tube is operated independently from standard 140 W control gear, the connexions being brought out to a 4-pin cap.

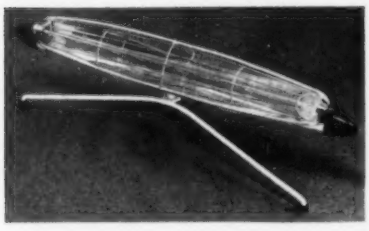
The lamp exhibits all the advantages of integral construction: fully protected arc tubes for reliable starting; ease of handling and maintenance; it will meet the demand for higher illumination values for street lighting combined with economies in power consumption and equipment.

Dimplex Infra-red Heaters

A new range of domestic and commercial infra-red fires and heaters was introduced this autumn by *Dimplex Ltd*. All the models have the same type of spiral element encased in a toughened silica sleeve; the reflectors are of anodized aluminium, either in 'natural' or 'copper' colour; the end-caps are of die-cast aluminium finished in black heat-resisting stove enamel. They are supplied with the elements in position and completely wired back to the terminal block —thus saving installation time and cost.

Illustrated here is the new 750 W domestic infra-red fire, which provides beamed broad-front radiant heating. The 1500 W model is similar in styling and incorporates two units (elements and reflectors) mounted one above the other and separately adjustable, so that the two beams of heat can be separately directed upwards or downwards as desired. Overall dimensions are as follows: 750 W model 32 in (81·3 cm) long, 10 in (25·4 cm) deep, 9¾ in (24·8 cm) high; 1500 W model—32 in (81·3 cm) long, 9½ in (24·2 cm) deep, 17¼ in (43·8 cm) high.

There are two commercial heaters—with 750 and 1500 W loading respectively—designed for overhead heating and especially suitable for shops, stores, offices, workshops, and similar locations. They can be suspended either by chain or conduit. Overall dimensions are: 750 W model—32 in (81·3 cm) long, 5 in (12·7 cm) wide, 4¼ in (10·8 cm) high; 1500 W model—same length and height, but 10 in (25·4 cm) wide.



The Dimplex 750 W domestic infra-red fire

Low Frequency AC Voltmeter

Crompton Parkinson Ltd have recently developed a special type of voltmeter to deal with the problem of reading steady rms voltage values on very low frequency 3-phase ac supplies.

A case in point arises in the operation of control rods in a nuclear reactor by very low speed motors on a 3-phase ac supply with a frequency varying from 0 to 2 c/s. In such a case, the instantaneous value of the voltmeter varies so slowly that the pointer of an ordinary voltmeter has time to follow it instead of indicating the steady rms value.

The new *Crompton Parkinson* instrument is basically a dc moving coil voltmeter operating through a phase-splitting network with full wave rectification. This network produces twelve impulses per cycle across the instrument movement, so reducing the magnitude of the applied ripple voltage and increasing its frequency. The voltmeter therefore indicates the rms value of an applied 3-phase voltage at any frequency from 0 to 2500 c/s. It is stated that tests have shown that the pointer deviation on either side of the mean indication is not more than 0·3 per cent at 2 c/s, 0·7 per cent at 1 c/s, and 5 per cent at 0·04 c/s.

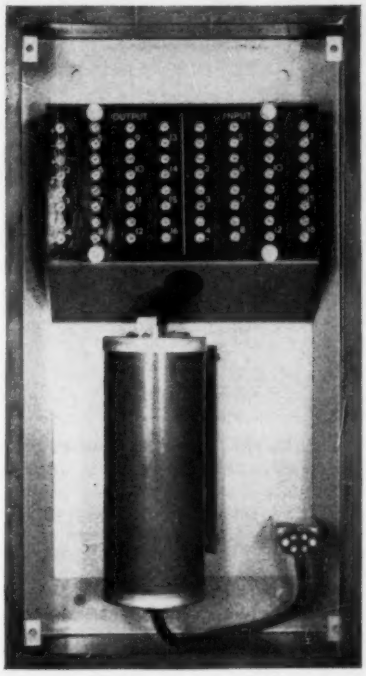
The instrument is available in both switchboard and portable forms.

'Sunvic' Cold Junction Box

Where large numbers of thermo-couples are installed at a distance from their indicating or measuring points, the cold junction boxes recently introduced by *Sunvic Controls Ltd* offer certain specific advantages. By enabling thermo-couple leads to be gathered at a central point where they are automatically compensated, the Sunvic junction boxes eliminate the need for long lengths of compensating cable and permit the distance from the junction box to the measuring or indicating points to be covered by ordinary copper cable, with a saving in cost stated to be of the order of one-third.

In nuclear reactor and power station applications, for example, where large numbers of thermo-couples are in use, these boxes provide a ready means of marshalling thermo-couple leads on to the plant, and the use of multi-way armoured copper cables to a centralized control room also keeps the external impedance in the thermo-couple measuring circuit down to reasonable limits.

Another advantage claimed for the boxes is their greater accuracy as compared with normal methods of compensation. They are stated to maintain a given temperature to ±0·1 deg C—an order of accuracy essential for most forms of data handling equipment.



The Sunvic cold junction box

As will be gathered from the illustration, the boxes are designed to accommodate 16 pairs of copper constantan leads, a cold junction thermostat set to maintain a temperature of 60 deg C±0·1 per cent, and the 16 thermo-couples required for the compensation of the constantan wires. Copper leads from the plant thermo-couples are looped across terminals in the box to the outgoing cable without need for any other compensation. There is provision for a test thermometer to be inserted through the top of the box into the thermostat to check the latter's performance. Cable entries are provided to suit customers' requirements, but cable glands are not supplied.

Lightweight Signalling Lamp

The General Electric Co Ltd has now placed on the market a lightweight, high intensity traffic control signalling lamp which, it is stated, has been successfully tested over a distance of 4 miles (6·4 km) transmitting signals into bright sunlight.

The lamp has been designed for easy use in the hand; it weighs 4½ lb (2·0 kg) and is very compact—7 in (17·8 cm) in diameter and 7⅝ in (19·7 cm) long. It incorporates an anodized aluminium reflector of 6⅜ in (16·2 cm) diameter producing a narrow well-defined beam which minimizes the risk of signals being received by two adjacent aircraft simultaneously. This risk is further reduced by the inclusion of special shutters instead of the more usual tilting reflector mechanism for signalling in code; these

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THE project to link the electricity supply systems of Britain and France by an underwater cable* was brought a stage nearer fulfilment when a sea trials programme was carried out in mid-Channel during September and October.

It will be recalled that the British and French electricity authorities—the Central Electricity Generating Board and Electricité de France—have decided to use high voltage dc transmission instead of an ac link. This has the advantages, among others, of requiring only two submarine cables instead of four and of providing an asynchronous connexion so that the frequencies of the two grid systems can be regulated independently.

The cables which are finally to be laid will be some 30

The MV 'Dame Caroline Haslett' taking on board the special gear for simultaneous laying of the two cross-Channel cables

miles (48 km) long between the English coast near Dungeness and the French coast just south of Boulogne, and will lie at a maximum depth of 200 ft (61 m). Half the cable will be made and laid by British manufacturers and the other half by French manufacturers, and the two halves will be joined at approximately mid-Channel.

British Insulated Callender's Cables Ltd and Siemens Edison Swan Ltd have been commissioned to undertake the work jointly for the CEGB, and for the sea trials each company manufactured one 880 yard (805 m) and one 200 yard (183 m) length of cable. They were made to slightly different designs in order to provide data which will help to determine the final design of the cable and accessories. The cable conductor is 0·525 in² (339 mm²), with impregnated paper, solid type dielectric to operate at 100 kV dc conductor-to-earth. The insulated core is lead sheathed, the lead being protected from chemical action by an impervious covering and from mechanical damage by heavy galvanized steel wires, with an overall covering of impregnated jute. The external diameter of the cable is 3·07 in (7·8 cm) and the weight 36 lb per yard (14·5 kg per metre).

As the cross-Channel link will consist of two single-core cables carrying up to 800 A go-and-return, at a conductor-to-conductor voltage of 200 kV dc, the presence of two such cables on the sea bed would give rise to significant interference with ships' compasses if they were laid more than a few feet apart.

One of the main purposes of the sea trials was, therefore, to confirm the technique of laying simultaneously two cables in a depth of 18-19 fathoms (33-35 m) at equal tension and separated by not more than 10 ft (3·05 m). Other purposes were to confirm the practical technique for repairing the cables by the jointing-in of new lengths and to obtain as much information as possible from electrical and physical tests during the trials, and afterwards in the firms' laboratories.

The trials programme consisted of the simultaneous laying of the two 880 yard (805 m) lengths of cable at not more than the required 10 ft (3·05 m) apart. The cables were then severed by an explosive charge; the ends on each side of the fracture were brought to the surface and the cable repaired by jointing in the two 200 yard (183 m) lengths. The distant ends of the original cable were then jointed together to form a loop for electrical continuity and resistance tests at $\pm$300 kV. The whole of the cable was then recovered for critical tests and physical examination in the laboratories.

Considerable use was made of underwater ciné and still photography, and in this work and for the placing of the explosive charges, the British firms had the cooperation of a midget submarine supplied by the Compagnie pour l'Exploitation Internationale des Procédés Rebikoff, and skin divers of the Société Générale de Travaux Maritimes et Fluviaux.

The ship selected for the trials was the MV *Dame Caroline Haslett*, a 2700-ton collier owned by the CEGB and specially modified and equipped with cable-laying and handling gear designed to ensure exactly simultaneous and even laying of the two cables.

It is hoped to lay the permanent cables during the summer of 1960 and to have the cross-Channel link available for load during the winter of 1960/61, giving an interchange of 160 MW between the British and French grid systems.

* THE BEAMA JOURNAL, November 1956, p 156; November 1957, p 175.

New equipment and processes

280 W Integral Sodium Lamp

Introduced last month by *The General Electric Co Ltd*, the new Osram integral sodium lamp rated at 280 W has a light output of 16,800 lumens, which is comparable with that of the 400 W mercury lamp and represents some 85 per cent more light than the 140 W sodium lamp with a separate jacket.

The integral jacket has the same dimensions as the previous Osram 140 W integral lamp, but houses two arc tubes rated at 140 W each. Efficiency is given as 60 lumens/watt throughout an average life of 4000 hours. Each arc tube is operated independently from standard 140 W control gear, the connexions being brought out to a 4-pin cap.

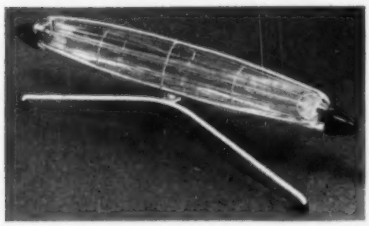
The lamp exhibits all the advantages of integral construction: fully protected arc tubes for reliable starting; ease of handling and maintenance; it will meet the demand for higher illumination values for street lighting combined with economies in power consumption and equipment.

Dimplex Infra-red Heaters

A new range of domestic and commercial infra-red fires and heaters was introduced this autumn by *Dimplex Ltd*. All the models have the same type of spiral element encased in a toughened silica sleeve; the reflectors are of anodized aluminium, either in 'natural' or 'copper' colour; the end-caps are of die-cast aluminium finished in black heat-resisting stove enamel. They are supplied with the elements in position and completely wired back to the terminal block —thus saving installation time and cost.

Illustrated here is the new 750 W domestic infra-red fire, which provides beamed broad-front radiant heating. The 1500 W model is similar in styling and incorporates two units (elements and reflectors) mounted one above the other and separately adjustable, so that the two beams of heat can be separately directed upwards or downwards as desired. Overall dimensions are as follows: 750 W model 32 in (81·3 cm) long, 10 in (25·4 cm) deep, 9¾ in (24·8 cm) high; 1500 W model—32 in (81·3 cm) long, 9½ in (24·2 cm) deep, 17¼ in (43·8 cm) high.

There are two commercial heaters—with 750 and 1500 W loading respectively—designed for overhead heating and especially suitable for shops, stores, offices, workshops, and similar locations. They can be suspended either by chain or conduit. Overall dimensions are: 750 W model—32 in (81·3 cm) long, 5 in (12·7 cm) wide, 4¼ in (10·8 cm) high; 1500 W model—same length and height, but 10 in (25·4 cm) wide.



The Dimplex 750 W domestic infra-red fire

Low Frequency AC Voltmeter

Crompton Parkinson Ltd have recently developed a special type of voltmeter to deal with the problem of reading steady rms voltage values on very low frequency 3-phase ac supplies.

A case in point arises in the operation of control rods in a nuclear reactor by very low speed motors on a 3-phase ac supply with a frequency varying from 0 to 2 c/s. In such a case, the instantaneous value of the voltmeter varies so slowly that the pointer of an ordinary voltmeter has time to follow it instead of indicating the steady rms value.

The new *Crompton Parkinson* instrument is basically a dc moving coil voltmeter operating through a phase-splitting network with full wave rectification. This network produces twelve impulses per cycle across the instrument movement, so reducing the magnitude of the applied ripple voltage and increasing its frequency. The voltmeter therefore indicates the rms value of an applied 3-phase voltage at any frequency from 0 to 2500 c/s. It is stated that tests have shown that the pointer deviation on either side of the mean indication is not more than 0·3 per cent at 2 c/s, 0·7 per cent at 1 c/s, and 5 per cent at 0·04 c/s.

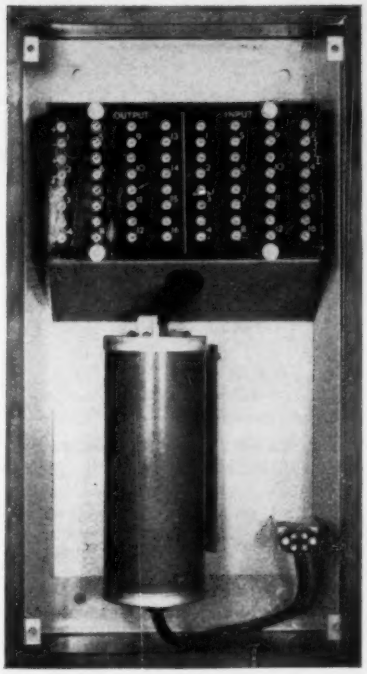
The instrument is available in both switchboard and portable forms.

'Sunvic' Cold Junction Box

Where large numbers of thermo-couples are installed at a distance from their indicating or measuring points, the cold junction boxes recently introduced by *Sunvic Controls Ltd* offer certain specific advantages. By enabling thermo-couple leads to be gathered at a central point where they are automatically compensated, the Sunvic junction boxes eliminate the need for long lengths of compensating cable and permit the distance from the junction box to the measuring or indicating points to be covered by ordinary copper cable, with a saving in cost stated to be of the order of one-third.

In nuclear reactor and power station applications, for example, where large numbers of thermo-couples are in use, these boxes provide a ready means of marshalling thermo-couple leads on to the plant, and the use of multi-way armoured copper cables to a centralized control room also keeps the external impedance in the thermo-couple measuring circuit down to reasonable limits.

Another advantage claimed for the boxes is their greater accuracy as compared with normal methods of compensation. They are stated to maintain a given temperature to ±0·1 deg C—an order of accuracy essential for most forms of data handling equipment.



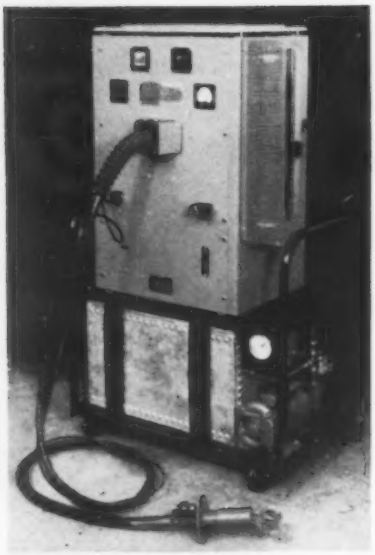
The Sunvic cold junction box

As will be gathered from the illustration, the boxes are designed to accommodate 16 pairs of copper constantan leads, a cold junction thermostat set to maintain a temperature of 60 deg C±0·1 per cent, and the 16 thermo-couples required for the compensation of the constantan wires. Copper leads from the plant thermo-couples are looped across terminals in the box to the outgoing cable without need for any other compensation. There is provision for a test thermometer to be inserted through the top of the box into the thermostat to check the latter's performance. Cable entries are provided to suit customers' requirements, but cable glands are not supplied.

Lightweight Signalling Lamp

The General Electric Co Ltd has now placed on the market a lightweight, high intensity traffic control signalling lamp which, it is stated, has been successfully tested over a distance of 4 miles (6·4 km) transmitting signals into bright sunlight.

The lamp has been designed for easy use in the hand; it weighs 4½ lb (2·0 kg) and is very compact—7 in (17·8 cm) in diameter and 7¾ in (19·7 cm) long. It incorporates an anodized aluminium reflector of 6⅜ in (16·2 cm) diameter producing a narrow well-defined beam which minimizes the risk of signals being received by two adjacent aircraft simultaneously. This risk is further reduced by the inclusion of special shutters instead of the more usual tilting reflector mechanism for signalling in code; these



The Radyne 1 kW mobile induction heating unit

shutters are actuated by a special spring-loaded mechanism which ensures rapid movement and are operated by a trigger in the pistol-grip handle.

By rotating an additional handle, red or green colour screens are brought into position, and an indication of the colour appears through an aperture at the rear of the lamp below the eyepiece of the sighting unit. The lamp houses an Osram 6 V 45 W bulb.

The lamp can also be supplied with a counterbalanced ceiling suspension system which allows the lamp to be used at any height between 4 ft (122 cm) and 9 ft (274 cm) above floor level.

Mobile Induction Unit

The Radyne 1 kW induction heating equipment manufactured by *Radio Heaters Ltd*, of Wokingham, Berks, is reported to be very popular with laboratories and other organizations for the firing of getters in electronic tubes and other vacuum devices. It is now available with an inexpensive mobile water re-circulator trolley which enables the unit to be easily moved around without trailing water leads and thereby increases its flexibility and overall usefulness. The reservoir tank has sufficient capacity for the equipment to be used continuously all day without overheating.

The hand applicator shown with the unit in the illustration has a standardized coil design for firing TV picture tube getters, and the same coil can be used if desired for heating the TV tube gun assembly.

'Metrovac' Oil Diffusion Pump

This is a high-speed 3 in (76 mm) diffusion pump developed by *Metropolitan-Vickers Electrical Co Ltd* for use in laboratory and small industrial vacuum applications such as electron microscopy, mass spectrometry, etc., requiring working pressures in the range 1×10^{-2} to 1×10^{-6} mm Hg.

The pump body is a water-jacketed cylinder of non-corrodible copper alloy enclosing an aluminium 3-stage jet system. A detachable heating unit comprising a metal-sheathed radiant element (standard loading 350 W) effectively lagged in a polished aluminium cover is fitted to the base of the pump.

Principal technical data are as follows: Pumping speed for air pressures below 1×15^{-3} mm Hg: 130 litres/sec unbaffled or 80 litres/sec with standard baffle valve. Limiting pressure at 15 deg C: 1×10^{-6} mm Hg using Apiezon oil 'B'. Highest permissible backing pressure: 400 microns (0·4 mm) Hg at heater loading of 350 W. The pump starts working in 15 minutes from cold, and stops working in the same time after switching off the heater. Air may be admitted 30 minutes after switching off.

Two Sciaky Welders

A new seam and roll spot welder and a new fully-automatic general purpose projection welder have recently been announced by *Sciaky Electric Welding Machines Ltd*, Slough, Bucks.

The first-named equipment—to which the type name of 'Ramut' has been given—has a nominal capacity of 250 kVA, and was produced by the firm to meet the requirements of one of the large engineering companies for a versatile circumferential and longitudinal machine for extremely exacting work.

The throat depth of the machine is 80 in (203 cm), and the shape of the top arm has been dictated by the physical nature of the work to be welded. The face-plate is made of high conductivity copper alloy and carries two hinged bottom arms, one for longitudinal and one for circumferential welding; either of these arms can be swung into welding position and clamped. The top electrode housing assembly rotates through 90 degrees to match up with whichever bottom arm is being used.

The method of driving the top electrode is claimed to be unique and to give complete versatility of machine setting. An individual motor mounted on the top arm drives the electrode through gearing and a drive shaft passing through the centre of the machine ram. This motor can either be run continuously for the welding of mild steels or as a roll spot welder for the heat resisting steels and light alloys. When run intermittently, the motor is energized and de-energized by the same electronic control that governs the timing and characteristics of the welding current.

The other equipment comprises a range of machines to be known as the 'Speedforge' range.

They are fully automatic general purpose projection welders designed for operation by unskilled labour and incorporating a number of special features.

Of these, the makers regard the one-piece frame as the most important. This is claimed to obviate the disadvantages arising from the usual practice of bolting the bottom arm on to an intermediate face-plate type of conductor; it is also claimed to eliminate the tendency to lever apart the top and bottom arms under welding pressure and to maintain rigid parallelism of the platens.

The frame houses the welding transformer and its tapping switch, and—in the smaller size machines—the primary current contactor. In the latter case, the electronic timing control gear is incorporated in a separate cabinet and mounted on top of the machine. The larger machines have a separate pedestal mounted cubicle which contains the timing controls, the primary ignitron contactor and a phase-shift heat control unit.

The fully interlocked control circuit is operated by a Sciaky three-channel electronic unit which provides variable timing for the squeeze period prior to the weld. This programme control has the following ranges: squeeze and hold—2 to 75 cycles; weld period—2 to 150 cycles. Additions or variations to the programme, such as two and three air pressures cycle, pre-weld heat and post-weld annealing currents, can be readily provided.

Two Hurseal Introductions

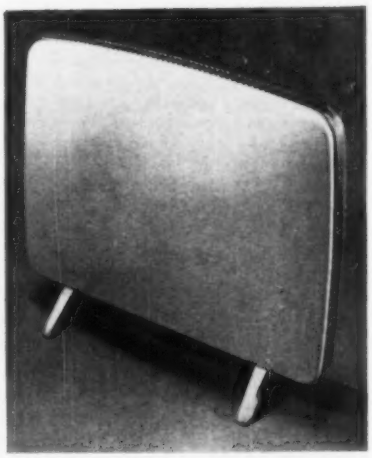
Illustrated here is a recent addition to the range of *Hurseal Ltd's* convector heaters, and it will be noticed that it is designed on smooth slim lines in a pleasing contemporary style. Its actual size is 25 in (63·5 cm) high, 28 in (71·1 cm) wide, and only $2\frac{1}{2}$ in (5·7 cm) deep.

The edges and the grilles at top and bottom are in a gold colour anodized metal which contrasts with the smooth cream back and front panels. A drop handle for carrying and the 3-heat control switch are located at the back of the heater.

It is designed for higher space heating efficiency, and with a maximum loading of 2 kW it gives rapid warming up. Two models are available for ac voltages of 230/250 and 200/210 respectively.

Hurseal have also introduced a time-switch control unit suitable for independent use with oil-filled electric radiators or other types of electric heaters with totally enclosed elements.

The unit will control up to 15 A on a 12-hour cycle; it is neat and unobtrusive and can be mounted permanently on the wall adjoining the 13 or 15 A plug point which it is to control.



The latest addition to the range of Hurseal convector heaters

Short-circuit Testing Plant for Miniature Circuit-Breakers

HIGH standards of design and performance have characterized the products of J. A. Crabtree & Co Ltd ever since the firm was started in Walsall, Staffordshire, in 1919, and began to make the now well-known 'underslung' tumbler switch. Rigorous testing at every stage of manufacture has always been an essential part of the Crabtree policy, and in fact the life-testing machine for tumbler switches evolved in the early 1920s was the prototype for a similar machine now installed in the National Physical Laboratory.

To-day, the metallurgical, chemical, and electrical laboratories at the Walsall factory are equipped with extensive facilities designed not only to meet British design requirements, but the firm claims to be one of the very few similar organizations in this country to possess certain specialized equipment to carry out tests for compliance with American, Commonwealth, and European specifications.

The latest addition to the laboratories is a short-circuit testing station designed for circuit-breaker and contactor testing on currents of up to 10,000 A at 440 V, 3-phase. It differs from the larger short-circuit testing stations used on the heavier side of the industry in that the test bay has been specifically arranged to suit tests on apparatus intended for manual operation by unskilled operators—for example, miniature circuit-breakers which might be installed in homes, hospitals, or other institutions and re-closed after short-circuit by a housewife, nurse, or similar persons. It is therefore important to be able to observe the test at close quarters and in quiet conditions, and the layout of the test bay has been planned to this end.

The test cell as seen from the test bay, with the remote control desk in the foreground

Power for the tests is supplied by an alternator rated for an output of 800 kVA, 440 V, 3-phase, 4-wire. It has a rotating salient pole field, and its designed reactance is such as to give the short-circuit current mentioned earlier. It is driven by a 100 hp squirrel-cage motor with a synchronous speed of 1500 rpm; both the motor and the alternator were made by Mather and Platt Ltd. Control of the motor is by an auto-transformer starter employing a Korndorffer circuit made by the Electric Construction Co Ltd. The two machines are directly coupled and, together with a directly-coupled exciter, are mounted on a common bedplate. Current is taken direct from the alternator terminals to a main circuit-breaker made by Erskine, Heap and Co Ltd, which has a normal continuous rating of 1000 A and a breaking capacity far in excess of the maximum short-circuit current of the alternator.

Between the circuit-breaker and the terminal board are reactors and resistors connected in each phase so that prospective current and power factor can be controlled down to 100 A. A 'make' switch is situated in the test cell and provided with an electronically operated point-on-wave control. Remote control of the whole station is afforded by a control desk in the test bay directly in front of the test cell and automatic safety devices and signals are incorporated.

The machine room, housing the alternator and its associated equipment, the resistors and the reactors, has forced ventilation and air filtration plant to exclude dust. Between this room and the test cell is a small dark room where oscillograms can be processed with the minimum of delay.

The test cell is also provided with a dc supply from a storage battery capable of giving 5000 A at 250 V and over 2000 A at 500 V, with suitable control resistors situated in the test station. Provision has also been made in the busbar systems for the connexion of transformers for higher test voltages.

Upwards of thirty observers can comfortably view the tests from the test bay. It has been found that, with manually controlled testing, it is desirable to adopt the practice of 'counting down' to the instant of switching to make sure that the observers are prepared and that none of them misses the critical moment because of surprise or fluttering eyelids.

The facilities afforded by this new testing station are regarded as essential by the firm to provide the design information required for the continual improvement of the quality of the product. It was emphasized by Mr J. A. Crabtree, the managing director, that circuit-breakers, when properly designed, are as safe electrically as fuses, and a good deal safer in the hands of unskilled users, since they cannot insert such things as copper wire, hair-pins, or paper-clips in circuit-breakers! He hoped that their use in Britain would grow as it has already done in America and many European countries.

The SBAC Exhibition, Farnborough

WIDELY and popularly known as 'the Farnborough Air Show'—but more correctly described as the 1958 Flying Display and Exhibition organized by the Society of British Aircraft Constructors—this year's event was the nineteenth of a series which began in 1932, and was again presented for the eleventh successive year at the Royal Aircraft Establishment at Farnborough, Hampshire, by arrangement with the Ministry of Supply.

The flying display which is staged every afternoon is, of course, the spectacular part of the show which captures the public's imagination and provides the headlines and stories in the non-technical press. Nevertheless, it is only a part of the whole event, and one which in any case is made possible only by the technical developments and equipment displayed and demonstrated in the accompanying exhibition.

Year by year, electrical and electronic techniques have played an increasingly important rôle in every aspect of aviation and, as with the new atomic industry, aviation is to-day completely dependent on electronics for its day-to-day operation, its safety, and its future progress.

Security requirements have, however, insisted on strict secrecy, so much so that until two or three years ago, no one was allowed to reveal, for example, that a guided missile contained any electronic components at all! Happily, recent relaxations in security requirements now permit publication of more—though still far from complete—information, and have made possible the inclusion in the show of the Guided Weapons Display, introduced for the first time last year, and considerably extended this year.

Increasing Airborne Electrical Load

Speaking to the press at a meeting during the show, Mr K. E. Harris, Chairman of the Aviation Committee of the Electronic Engineering Association, said:

'This exhibition again emphasizes what we in the electronic industry have known for years but which is only now being afforded public recognition: that aviation, civil and military, is increasingly and utterly dependent on electronics.

'No aircraft can be designed, built, tested, or flown without major electronic aid. So far as civil aviation is concerned, vast ground control communication networks are required to progress traffic, and radar and other electronic guidance systems are essential to expeditious operation. Apart from this, the aircraft itself carries increasing amounts of electronics. The Comet IV, for example, on its trans-Atlantic routes, will carry almost a ton of electronic equipment.

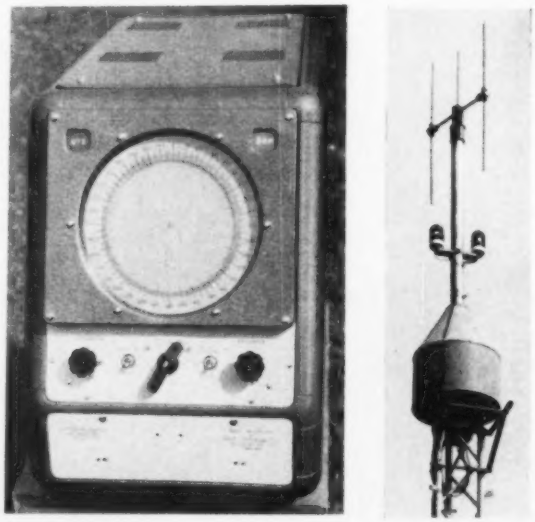
'The modern component developments are of the utmost importance in this respect, both to lighten the equipment itself and to make it possible to operate with smaller power supplies. Apart from its intrinsic importance in saving weight, the reduction of power consumption makes it possible to operate at high altitudes without the over-heating problems which have bedevilled us for years.

'The missile is nothing more than a violently destructive and highly expensive warhead built round an electronic guidance system.

'The ultimate usage of missiles for launching space platforms has no purpose other than to provide a carrier for an intelligence system. Initially, this intelligence system may be employed to tell us something about the conditions outside the immediate earth atmosphere. It is only useful to determine these conditions in order to transmit through space or to permit longer term operation in space, for example, to provide totally new navigational systems. It may be of interest to consider manned space platforms so that the intelligence can be transmitted by human agency. It is much more probable that any such usage will be entirely automatic, employing electronic techniques to do all the necessary work, and such arrangements offer the prospects of guidance and control systems which are not limited in the same way that earth-bound systems must be.

'To deal with the present, the safety of aircraft *en route*, and particularly in approaching the landing at airports, is a matter offering electronics its greatest challenge to-day.

'Aviation electronics, in the broad sense of equipments carried in aircraft, and communications and control and guidance systems, is a major industry itself. The annual output of this industry in this country is some



Automatic VHF/DF equipment by E. K. Cole Ltd, which incorporates a continuously rotating Adcock aerial

£100 million. Between one-fifth and one-quarter of this is exported.'

The two most noticeable trends in electronic development this year are the methods developed by the industry to solve the problems of controlling the traffic in the increasingly congested airways of this jet-propelled age; and the almost spectacular progress in reducing the size and weight of airborne equipment while increasing its strength and reliability. The end results must lead to increased flying safety and more economic operating techniques.

Simplifying Traffic Control

A few examples of these trends may be mentioned here. The work of traffic controllers is now becoming highly complex, and a new data handling equipment now under development by Marconi's was shown which simplifies their task by 'considering' all the available information on a situation and passing on to the human controller only the relevant information. The equipment also includes FPI (Future Position Indicator), which enables the controller to determine the time of arrival of an aircraft at a given point, or alternatively to determine where an aircraft will be at a given time, and so gives a warning of possible collision dangers in crowded air spaces in sufficient time for avoiding action to be initiated.

The use of high power, long range radar equipment is complicating the problem of handling radar information in the traffic control organizations, and has therefore led to the development of new equipment that can integrate information from more than one source. Display systems have been made more comprehensive and at the same time present the information in a more easily comprehensible form.

At the other end of the scale, advanced development had produced an air guidance system claimed by its makers, E. K. Cole Ltd, to be Britain's lowest-priced VHF automatic direction-finding equipment. It employs new methods of deriving bearing and sense from an Adcock aerial, giving a notably simple and reliable installation.

Lightweight Airborne Teleprinter

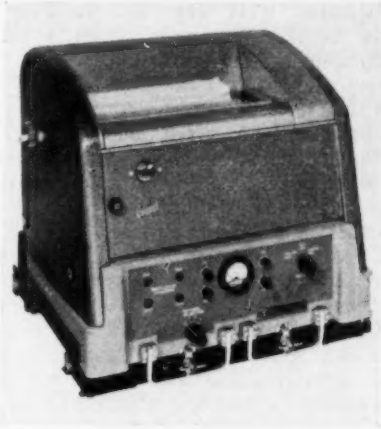
In the component field, the rapid developments in semiconductor technique have enabled these devices to be extensively adopted in place of valves, so bringing about quite spectacular reductions in size and weight of equipment and power supplies, accompanied by a marked increase in rugged reliability.

Notable examples of this trend are afforded by an IF amplifier exhibited by Standard Telephones & Cables that is only one-quarter of the weight of its valved counterpart and needs only one-twentieth of the power from the aircraft's electrical supply system.

Also developed by the same firm and using semiconductors instead of valves is a highly accurate radio altimeter, which indicates the height of an aircraft above the ground to less than hedge-hopping altitude—a matter of 2 ft (61 cm).

Perhaps one of the most striking examples of this trend is an airborne teleprinter equipment shown by Standard Telephones & Cables Ltd. It is able to receive and print out in plain language continuous weather reports at 100 words a minute, and is now in experimental use by, among others, BOAC on the Atlantic route. Again, the use of semiconductors has brought the weight down to only 45 lb (20 kg) and the power consumption is only 1·5 W.

Pye Telecommunications showed a particularly interesting overspeed and rotation indicator designed for the Rolls-Royce Conway engine, giving visual warning of engine overspeed by flashing lights on the flight engineer's or pilot's panel. It uses potted component 'bricks' on printed circuit bases for increased reliability, and its makers believe it to be the first application of semiconductors in airborne control equipment.



The compact light-weight airborne teleprinter equipment made by Standard Telephones & Cables Ltd

Even in such comparatively humble components as cables and plugs and pockets, marked developments have taken place in reducing size and weight and increasing reliability. Cables were shown (by BICC) capable of operating for a period of five minutes at a temperature of 1100 deg C under direct exposure to flame. One subminiature coaxial RF cable has an inner conductor of steel wire, copper covered and silver plated, measuring only 0·0124 inch (0·32 mm), polythene insulation, an outer braiding of copper and the whole sheathed in nylon, and yet the overall diameter is only 0·068 inch (1·73 mm).

Guided Weapons

This field of electronics is closely guarded by security requirements, and little can therefore be published. The opinion has, however, been stated at Government level that the British weapon control systems now being built and others that are in development are significantly ahead of anything else in the world.

Here, again, semiconductors are playing an important part in reducing size and weight, and increasing the reliability of the equipment.

Featured in the outdoor Guided Weapons Display were Seaslug—a guided missile for the Royal Navy—in a joint exhibit by the General Electric Co Ltd (Applied Electronics Laboratories), Sir W. G. Armstrong Whitworth Aircraft Ltd and the Sperry Gyroscope Co Ltd; the Thunderbird by the English Electric Co Ltd (Guided Weapons Division); the Bristol/Ferranti Bloodhound; the Short-Elliott general-purpose vehicle, recovery version, shown jointly by Elliott Brothers (London) Ltd and Short Brothers & Harland Ltd, and a line-of-sight, command control, anti-tank guided weapon by Pye Ltd (Telecommunications Division).

In the indoor exhibition, the British Thomson-Houston Co Ltd were able to reveal by official permission some restricted information on their 'Sting Ray' radar—the latest defensive radar to go into production at their new factory in Leicester. 'Sting Ray' is a mobile target tracking and illuminating radar, designed to 'acquire' a target in the shortest possible time and then to track it with a far greater accuracy than was required of earlier tracking radars. At the same time it 'illuminates' the target with energy that enables either the Bloodhound or Thunderbird type of missile to home on it with their built-in guidance systems. BTH were also showing NBC—a navigational bombing computer which is part of the bombing equipment of Britain's V bombers.

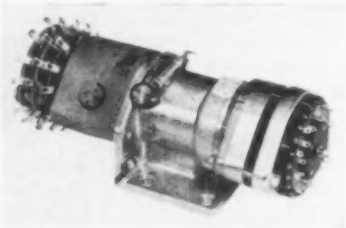
GEC were also given permission to show the radar equipment they have developed and are now producing for the de Havilland 'Sea Vixen', and were authorized to announce that it almost certainly has a higher performance than any other of its type now in service in the world.

Telemetry plays a highly important part in rockets and guided missiles, and EMI Electronics Ltd have for some time been prominent in this field, although permission has only recently been given for the release of any details. Thus they were able to show on their stand some of the most advanced telemetry equipment used to radio comprehensive data from rockets and missiles, together with the special techniques and some of the test equipment evolved to ensure the complete reliability of the telemetry apparatus in the exceptionally severe conditions under which it has to work.

Electrical Equipment

The trend towards reduction in size and weight and increased reliability, especially in high operating temperatures, was equally apparent in the electrical as in the electronic field. Another noticeable trend was towards a c power generation rather than d c. The three systems commonly in use in aircraft to-day are 28 V d c, 112 V d c, and 200 V a c at 400 c/s; there is as yet no standardized system, but a trend towards a c seems to be gaining ground.

One factor is, of course, the increasing power consumption of modern aircraft—now getting on towards 100 kW; another is that much of the equipment either requires or can easily be operated by a c (with rectifiers

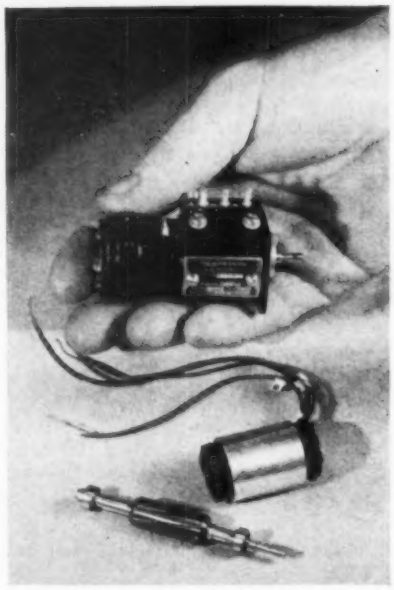


Subminiature telemetry high speed switch made by EMI Electronics Ltd

available for essentially d c operated components), and weight can be saved since alternators can produce a greater output for a given frame size than a d c generator.

A c generation through the medium of a variable-ratio, constant speed drive and a brushless alternator coupled to the output shaft was shown by the English Electric Co Ltd. The alternator is air cooled and incorporates rotating silicon rectifiers. Used in conjunction with this constant frequency system were alternator panels providing control and protection facilities, and frequency and load controllers which monitor the basic governor setting and equalize the load distribution between alternators running in parallel.

Newton Brothers (Derby) Ltd were also showing a c and d c generators for main services, together with high frequency alternators, split field motor generators, automatic carbon pile voltage and current regulators, and rotary transformers and convertors.



Typical small BTH aircraft a c motor showing the stator and rotor separately

A representative range of a c and d c motors and generators was shown by BTH, including very small induction motors for radar servo-control circuits and blower units. Ferranti had a transformer-rectifier unit in which size and weight had been reduced to the minimum. It uses silicon rectifiers of high stability and conservative rating, thus conducing to long life and reliability, and a six-phase output arrangement with balance coil to give the best regulation and minimum transformer losses.

A new single- or three-phase inverter for converting 150 or 200 V a c to 400 c/s was shown by E. K. Cole Ltd, and a wide range of rectifiers was displayed by the Westinghouse Brake & Signal Co Ltd, including high temperature lightweight selenium, copper oxide and silicon rectifiers for aircraft power supplies; selenium and germanium rectifier equipments for the aircraft and associated industries and for general industrial d c power supplies.

Batteries

Solar activated cells provided something of a novelty on the stand of Chloride Batteries Ltd, where they were demonstrated. They are activated by the sun's rays and are used to re-charge small orthodox batteries, so that the variable output of the solar cell, which naturally depends on the intensity of the sunlight, can be converted to a steady usable supply by the orthodox accumulator. This combination is used in space satellites and enables radio transmitters to keep working for much longer periods

than would be possible without making use of solar energy.

Various types of Exide aircraft batteries were shown, including 24 V batteries capable of high output and specially ventilated for satisfactory operation in high temperature conditions. Specially developed for guided missile operation were three small unspillable portable batteries capable of a very high output for their weight and volume.

A lightweight, ventilated, and unspillable airborne battery was introduced by Joseph Lucas Ltd, in three different sizes and types of terminal. Other types of Lucas batteries, some with a maximum capacity-to-weight ratio for heavy duty conditions, and some for ground starting units, were also shown.

Cables

Many specialized types of cable particularly applicable to guided missile requirements were the principal items shown by British Insulated Callender's Cables Ltd. 'Uniefglas' is a cable designed for continuous operation up to a maximum temperature of 240 deg C. It has a p t f e and glass insulation (developed by BICC) which is resistant to all aircraft oils and fuels and abrasion, and remains flexible at temperatures down to – 75 deg C.

P t f e equipment wires designed for continuous operation up to 250 deg C were also shown, and a new development was p t f e multicore cable, which is basically the equipment wire formed into a cable with from 3 to 25 cores. Also shown were irradiated polythene equipment wires with improved soldering properties, and in types capable of continuous operation up to 100 deg C, or up to 120 deg C for 1500 hours and shorter periods (about 1 hour) up to 250 deg C.

The Tersil cable which will function for five minutes at 1100 deg C has already been mentioned, as has the subminiature co-axial r f cable, which is one of a range with overall diameters of less than 0·1 inch (2·54 mm).

A variety of cables for aircraft wiring were also shown by W. T. Henley's Telegraph Works Co Ltd, together with winding wires, flexible cords, electric soldering wires and self-adhesive polythene tape. Also allied to this group of products were some of the ICI exhibits: 'Fluon' (p t f e) and 'Darvic' (rigid p v c) plastics used for aircraft electronic and control equipment, and a range of oil-resistant components made from 'Butakon' rubber.

Welding and Other Equipment

Welding processes were featured by the specialist firms in this field, including the following.

British Oxygen Gases Ltd, who showed the development of welding and cutting in the aircraft industry, including automatic 'Argonarc' welding which is used, among other applications, for the fabrication of jet tubes for Armstrong-Siddeley 'Sapphire' engines.

The system of frequency conversion three-phase balanced-load resistance welding equipment developed by Sciaky Electric Welding Machines Ltd was prominently featured on their stand, with a typical control cabinet for a Sciaky three-phase light alloy welding machine for aircraft production.

Instruments

This group of products naturally covered a very wide field, embracing an extensive range and diversity of engine, flying, measuring, and navigation instruments. Many of the firms already mentioned in this review were showing specialized instruments appropriate to their particular activities, and in the general field of instrumentation the following exhibits were noteworthy.

Dowty Equipment Ltd, who specialize in aircraft hydraulic systems and components, were also showing electronic tachometers for gas turbine testing, and a wide range of switches and indicators. Elliott Brothers (London) Ltd displayed on their Indoor Exhibition stand a range of flight instrument and control systems, fuel flowmeter systems, a rate gyro, and an angular accelerometer. Rate gyroscopes and test gear were also shown by the English Electric Co Ltd, and gyro flight instruments and gunsights by Ferranti Ltd.

A range of electrical equipment and electronic instrumentation and test apparatus was to be seen on the stand of Denis Ferranti Meters Ltd, and Marconi Instruments Ltd had a comprehensive display of telecommunication test equipment for checking the performance of airborne and ground-based radio installations, and a range of over 100 instruments designed to meet the requirements of civil and military electronic engineers.

From the range of electronic and electrical components shown by Salford Electrical Instruments Ltd may be mentioned their new rugged quartz crystal units, complete ferrite assemblies, and aircraft circuit-breakers. Another very comprehensive exhibit was that of Sangamo Weston Ltd, which included instruments for indicating temperatures, pressures, control surface positions, turbine speeds, and electrical power; navigational aids; ground test sets, an ice-warning system, relays, and a variety of electrical measuring instruments. Special emphasis was given to their new jet pipe temperature indicators with circular scales and designed for direct connexion with a Chromel/Alumel type of thermo-couple. They incorporate automatic cold junction compensation and are suitable for 8 or 25 ohm systems.

Synchros and small motors, as well as a range of flight control and flight instrument systems, were featured by Smith's Aircraft Instruments Ltd. Of particular interest was the new size 07 servo motor—a two-phase squirrel-cage induction motor with an overall diameter of only

A variable-ratio constant-speed drive coupled to a brushless alternator developed by English Electric Co Ltd for aircraft a c power supplies

§ in (15·88 mm), and the range of 400 c/s motors, which includes hysteresis, drag-cup and squirrel-cage motors up to 2¼ in (57 mm) in diameter.

Equipment

The Equipment Exhibition, which was a separate entity from the main Indoor Exhibition, comprised principally, though not entirely, a variety of ground equipment. Here David Brown Industries Ltd showed their 900 Turbo-Taskmaster tractor and the 40 b h p diesel engine 6 speed Brockhouse torque-converter-coupling.

Electrical servicing and starting units were displayed by Houchin Ltd, including a fully integrated multi-purpose electrical trolley, a standard 20 kW d c trolley, and a high frequency radar and radio ground servicing trolley. Airtech Ltd had the 'Aircon' air transportable container for mobile airfield radio installations, and a selection of pilotless aircraft electronic control equipment.

Among the other exhibits which cannot conveniently be grouped under the various headings of this review were, for example, a comprehensive range of panel illumination systems, electroluminescent warning signs, roof cabin and navigation lights shown by Thorn Electrical Industries Ltd; and a 28 V d c transistor-operated system of fluorescent tubes for cabin lighting developed by the General Electric Co Ltd in conjunction with Vickers-Armstrong (Aircraft) Ltd.

Another notable exhibit was that of Redifon Ltd, which was representative of this firm's activities in the field of radio communications and included transmitting and receiving equipment, radiotelephones and communication receivers, frequency shift terminal equipment, and a 16-channel high-speed telemetering data recorder. On an adjoining stand they showed various aspects of synthetic training devices together with examples of equipment, servos, computers, and so on used in flight simulators.

Among the manufacturers of components and materials showing representative selections of the products in which they specialize were Bakelite Ltd (moulding materials, resins, and extrusion compounds); Docker Bros (aircraft paint materials and industrial finishes); Fibreglass Ltd (including decorative glass drapes and a new insulation mat); Garringtons Ltd (compressor and turbine blades, general forgings and hand tools); Heenan & Froude Ltd (engine thrust measuring and propeller test plant); Manchester Oil Refinery Ltd (specialized oil products, mechanical seals, fuel pumps, etc); Rubery, Owen & Co Ltd (bolts, nuts and screws, sheet metal components, machines assemblies, and valve gear); Tufnol Ltd (a wide variety of components, sheets, rods, and tubes made from Tufnol); Turner Brothers Asbestos Co Ltd (asbestos felts, flock, and powder, Duraglass woven glass fabrics, and other materials); Henry Wiggin & Co Ltd ('Nimonic' wrought high temperature alloys, 'Nimocast' heat-resisting casting alloys, and other specialized nickel alloys).

NOTES (*continued from page 157*)

'People and Plastics—Polyethylene'

This is the title of an interesting film recently produced by the publicity department of *Bakelite Ltd* with the intention of developing public confidence in plastics in general and polyethylene in particular. Since it is designed as a general interest film, it is necessarily non-technical in its approach, but it does include many sequences of considerable interest to the technician.

The producers have embarked on a formidable task in trying to cover in a film of reasonable length the story of the production and fabrication of polyethylene, and the extremely wide fields of its application in a great variety of technical and domestic uses. In the result, the running time of 41 minutes is not too long to hold the viewer's interest, but long enough to do reasonable justice to the subject matter.

From the opening sequence in a London park, introducing polyethylene in its well-known guise as a hygienic and convenient packaging medium for foodstuffs, the film goes on to the production of polyethylene film and shows the sequence of all the manufacturing processes involved. It then introduces some of the more important uses of polyethylene sheet, for example in horticulture and building, and thence to its multifarious applications in packaging—from machinery and machine components and sausage skins to bananas in bulk packed for shipment.

The next processes shown are those of polyethylene coating on paper and other base materials, and the production of pipe in all sizes from small diameter tube as used in ball-point pens to larger diameter pipes for industrial applications.

Then on to one of the most important of its uses—the insulation of electric cables, showing the manufacture of the sub-Pacific cable, co-axial cable for VHF purposes, and so on.

The closing sequences deal with injection moulding and some of the many products made by this technique, which brings the story back to the home and the domestic uses of polyethylene.

Copies of the film—in 16 mm Kodachrome colour—are available from Bakelite Ltd (Publicity Dept), 12-18 Grosvenor Gardens, London, SW1.

Post Office Telecommunications Journal

In his paper* to the British Electrical Conference in Brussels last May, Sir Gordon Radley, Director-General of the British Post Office, mentioned that by 1970 three-quarters of all long-distance calls in the United Kingdom should be dialled by the callers, and plans for international subscriber dialling were being made by the appropriate International Consultative Committee.

The Summer (August) issue of the *Post Office Telecommunications Journal* contains the first article explaining in detail the general principles of STD (Subscriber Trunk Dialling), which will start at Bristol next month; thereafter it is hoped to have it working in more than 100 towns by the end of 1961. The plans for this extension, and particular features of the system, will probably be dealt with in subsequent issues of the *Telecommunications Journal*.

Other interesting features of this issue are a description of the new switching centre for the tape relay telegraph system for British Road Services; an article on the development and application of line connectors as a convenient means of applying common-user principles to a local line network; an outline of the theory behind quality control, and the text of Sir Gordon Radley's paper at the Brussels Conference reprinted from THE BEAMA JOURNAL.

Copies can be obtained from the Editor, *Post Office Telecommunications Journal*, Public Relations Department, Headquarters, GPO, London, EC1, price 1s 6d. The annual postal subscription rate for the four quarterly issues is 6s 6d to any address at home or overseas.

* THE BEAMA JOURNAL, **65**, No 2, May 1958, p 51.

The 25th National Radio Exhibition

THIS year the National Radio Exhibition celebrated its silver jubilee at its customary venue—Earl's Court, London—with what was undoubtedly the best looking and most attractively staged show of the whole series. Nor was the interest confined to display and décor; technically there was much to engage the attention of the well-informed visitor, while 'Stereo Sound', which was the main theme of the show this year, appeared to capture the interest of all the visitors, technical and non-technical alike.

Television having provided the major interest of the show in recent years, there was understandably a slight misgiving in the minds of the organizers that this year's emphasis on sound radio and reproduction might take the edge off the popular appeal of the exhibition. In the event, they need not have worried; the public came in as many thousands as in previous years to investigate this new stereo sound, and the demonstration rooms in the Audio Hall (a new section introduced this year) were full all day and every day.

What is Stereo sound? And why has it suddenly caught the public's imagination in a matter of weeks?

To answer the first question, stereo sound in this context is a means of reproducing *in the home* music (or any other sound, for that matter) with a degree of spatial distribution which gives it a sense of perspective, breadth, fullness—and therefore realism—impossible of achievement with previous reproduction techniques. No longer, for example, does the sound of a symphony orchestra appear to be coming out of the concert hall through a hole in the wall; stereo sound gives the complete illusion of the orchestra spread out right across the platform, with all the instruments in their proper audio perspective.

Stereo sound has been known and used in the cinema for a number of years, but cinema techniques depended on the use of at least three, and more usually four or five, sound channels and a multiplicity of loudspeakers, and were therefore impracticable for domestic application.

The problem of obtaining true stereophonic reproduction through only two channels was fundamentally solved by A. D. Blumlein in the late 1920s and early 1930s, and his comprehensive patent of 1931 laid the foundations of the system that has now been adopted by all the recording organizations: a single groove modulated by two separate signals, the axes of the stylus motion being at 90° to each other and at 45° to the surface of the record.

However, the very first introduction of stereo sound for the domestic market was by EMI in 1955 and demonstrated by them in a specially built demonstration theatre at that year's Radio Show. The record medium was tape, and although the system was well received, it could achieve only a limited popularity, since it appealed only to existing owners of tape-reproducing equipment who were prepared to add a stereo tape head and a duplicate amplifier and speaker channel, or to enthusiasts who were in a position to buy a complete stereo tape equipment.

Nevertheless, stereo sound had made its debut and public interest had been awakened. The next logical step—and one on which all the recording organizations had been working for some time—was to put stereo on discs and so make it available at a reasonable cost to the vast public all over the world which for many years has been buying records in ever-increasing quantities. Stereo discs were launched in a big way at this year's Radio Show, accompanied by a wide range of reproducing equipment in a variety of styles and prices, all as easy to handle as the now familiar radiogramophone. This is the answer to the second question posed earlier in this review.

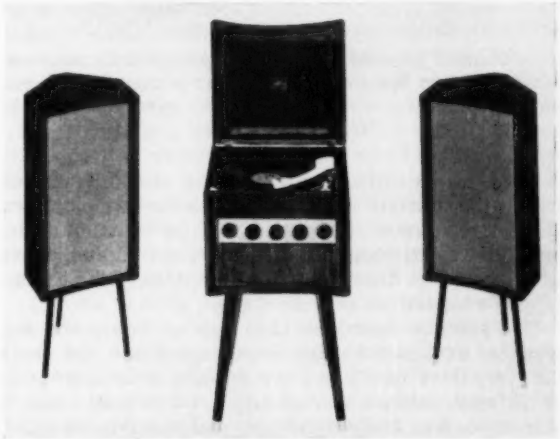
Whatever the physical shape and layout of the reproducing equipment, the fundamental components of any stereo system are:

(a) A pick-up capable of reproducing the two separate signals from the 45/45° modulated record groove.

(b) Two (preferably matched) pre-amplifiers and power amplifiers.

(c) Two similar loudspeakers capable of being spaced at a lateral distance up to about 8 ft and subtending an angle of 60-90° towards the listener.

This arrangement is accepted by most engineers as the optimum, but it is also realized that not every domestic listening room can conveniently accommodate three such pieces of equipment and several different and ingenious alternatives were to be seen at the Show.



Typical of the 'three unit' arrangement is this stereo record reproducer introduced by EMI Sales & Service Ltd

One method is the conventional arrangement of one cabinet housing the pick-up and turntable unit and the two amplifier channels, and two 'satellite' speakers housed in their own cabinets for standing on the floor or hanging on the wall in opposite corners of the room.

Another scheme is one which makes for greater compactness and also reduces the cost, although in some ways

it is less convenient in use. The practice here is to house turntable unit, both amplifiers and one speaker in the main cabinet, with the second speaker in its own cabinet standing in the opposite corner.

Using this arrangement, some manufacturers have designed their equipment from the outset for stereo reproduction. Others have aimed at greater flexibility by designing the main unit initially for single-channel reproduction, using a conventional microgroove pick-up, single amplifier channel and loudspeaker, but with provision for subsequent conversion to stereo. (With the inclusion of a radio unit, such an instrument is virtually a conventional radiogram.) Conversion to stereo is then merely a matter of replacing the conventional pick-up head with a stereo head, and adding a second unit containing a duplicate amplifier and speaker in one cabinet by means of the connexions already provided on the main equipment.

A third alternative carries compactness a stage further by housing all the three units in one cabinet, but the lateral separation of the speakers essential to provide the stereophonic effect was achieved in different ways by

An alternative favoured by many manufacturers for stereo reproduction is to house all the equipment in one wide cabinet, with the speakers at either end—as in this stereo radiogram by 'His Master's Voice'

various manufacturers. Perhaps the simplest was to mount the speakers at either end of a very wide cabinet, giving a separation of some 3 or 4 ft. (A variation of this method was to mount the speakers on sliding panels which could be drawn out from the sides of the cabinet to give a separation of some 6 ft.)

Yet another ingenious idea was to house the two speakers in separate cabinets of such a size and shape that they fitted neatly like two drawers in the lower part of the main cabinet, so that they could be used either in that position or easily withdrawn and placed more widely apart.

Stereo players were not confined to the static floor standing cabinet style, and it may be convenient to mention the portable reproducers here, because the methods adopted to achieve speaker separation fall broadly into the same plan. Some had one speaker in the body of the case and the other in a removable lid; others had a fixed speaker in the lid and a removable one clipped into the lid beside it. Yet another arrangement was to hook both speakers to the sides of the case and pointing outwards at an angle to give a diffusion of the sound, with a further provision to unhook them altogether and extend them to the corners of the room if desired.

Finally, there was an entirely different arrangement adopted by one manufacturer. Here the main cabinet housed turntable and pick-up unit, the twin amplifiers and one bass speaker only, with a frequency response up

Transportable television receivers are gaining ground. This is a typical 'His Master's Voice' model with a 17 in (43 cm) tube

to 300 c/s. This meant that the two satellite speakers were called on to handle the middle and top frequencies only and could therefore be made quite small, light, and comparatively cheap. This plan also economizes on the cost of one heavy bass speaker.

The technique of this arrangement depends on the theory that bass notes up to about 300 c/s contribute nothing to the stereo effect, although this theory is firmly rejected by other engineers. In fact there is a good deal of difference of opinion about stereo theory and, as in many another field of practical application of theoretical principles, it may be that considerations of economy,

Another example of a 'three unit' stereo radiogram by Philips Electrical Ltd

compactness, and convenience enforce some degree of compromise between the practical and the ideal. The fact remains, however, that the difference between single channel reproduction and stereo is as startling and impressive as that of listening to an orchestra through a hole in the wall, and then going into the concert hall and hearing it in all its full dimensional realism.

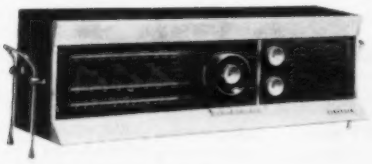
Television Developments

There were no startling innovations this year—a fact which indicates that design has substantially reached a stage of stability, although this does not by any means imply that it is static. Observable trends were the predominance of 17 inch (43 cm) tubes as the most

This GEC television receiver well exemplifies the more compact cabinet styling made possible by the 90° deflection cathode-ray tube

favoured size for domestic viewing; a falling-off in the number of 21 inch (53 cm) models; a small increase in the number of sets with 14 inch (36 cm) tubes, and a decisive increase in the number of portable receivers—there were 18 models, nearly double those of last year. Four of them incorporated 17 inch (43 cm) tubes.

The results of the intensive development work carried out by the cathode-ray tube manufacturers were very apparent in this year's television receivers. It is not so long ago that a 70° angle of beam deflection was hailed as 'wide angle', yet to-day tubes with a 90° beam deflection



A notable example of modern radio set design—the Ferguson 'Futura'

are in general use. This has meant a reduction in the overall length of the tube, and has therefore made it possible for set designers to produce more compact chassis housed in less bulky and more graceful cabinets. This trend will be even more marked when the tube manufacturers make available (next year?) the 110° deflection tube now under development.

Another notable feature was the increasing attention now being given by nearly all manufacturers to ease and speed of servicing. In many cases, chassis layouts have been radically overhauled to give greatly improved access to components, printed circuit panels, and the like with a minimum of dismantling. Plug-in line output transformer systems and replaceable printed circuit group panels are significant examples of this advancing trend.

Radio Receivers

Here, again, there were no fundamental changes to be seen. VHF (f/m) reception continues to make steady headway; some manufacturers are now producing this type of receiver exclusively, while still more television receivers were available with VHF radio incorporated.

Semiconductors (transistors) have been influencing receiver design for some years now, although perhaps so far only in a small way, but this year most manufacturers

An all-transistor portable radio receiver by Ferranti. It uses six transistors in a printed circuit and is powered by one inexpensive dry battery

were offering transistor models and the range of choice from pocket portables upwards is now wide. Car radio is, of course, an obvious application of the special advantages of semiconductors, and the three models shown this year are certain to be the forerunners of many more in the future and the beginning of the end of the vibrator type.

Tape recorders, which have enjoyed a steadily increasing vogue for several years, were present in greater numbers and variety of models and prices than ever. The main trends are towards greater flexibility in operation, increased facilities (including, in many cases, conversion to stereo), and improved frequency response, especially at the lower tape speeds.

Exports of radio equipment have shown an increase of more than four times in the post-war period, having risen from £10·2 million in 1947 to £44·1 million last year. The USA, with imports of over £4·5 million (most of it sound reproduction equipment), was again in 1957 the biggest buyer for the second successive year. Nearly 40 per cent of the exports were to Commonwealth countries and over 37 per cent to European countries. The radio industry expects to reach a new high level of exports this year.

Electronic Computer Exhibition

AN Electronic Computer Exhibition and Business Computer Symposium—the first event of its kind in Europe—is to be held under the patronage of HRH The Duke of Edinburgh at Olympia, London, from November 28 to December 4 this year. Instigated by the National Research Development Corporation, and organized jointly by the Electronic Engineering Association and the Office Appliance & Business Equipment Trades Association, the exhibition and symposium promises to be one of the outstanding business events of the year. In the exhibition, British computer manufacturers will show the great contributions they have made in the development and use of computers, not only the big mathematical machines, but also the medium-sized electronic computers particularly suitable for a wide range of applications in government establishments, industry, and commerce.

Up to the time of going to press exhibition space has been taken by 39 manufacturers, including the following BEAMA member-firms: British Thomson-Houston Co, Ltd, Elliott Bros (London) Ltd, EMI Electronics Ltd, EMI Sales & Service Ltd, English Electric Co Ltd, Ferranti Ltd, Metropolitan-Vickers Electrical Co Ltd, Siemens Edison Swan Ltd, and Standard Telephones & Cables Ltd.

The Business Computer Symposium, which will be held at the same venue as the exhibition on December 1, 2, and 3, will be in six sessions, and speakers have been drawn from a wide range of state-controlled and private enterprise. In addition to this business symposium there is a Scientific Symposium organized by the National Physical Laboratory which will be held at Teddington from November 24 to 27. We hope to deal with all three parts of this event in our February 1959 issue.

Here is the programme of the Business Symposium:

Chairman

The Earl of Courtown (Imperial Chemical Industries Limited)

Opening Address

Computers: Retrospect and Prospect	Earl of Halsbury, FRIC, FInstP

Session 1

Payroll, Production, and Sales Applications	N. C. Pollock, MBE (Stewarts and Lloyds Ltd)
The Computer as an Aid to Production Management	J. W. Grant, FSS (The British Tabulating Machine Co Ltd)
Computer Services in the United Kingdom	D. Wragge-Morley (Scientific Correspondent, *Financial Times*)

Session 2

Chairman: Mr Lewis Wright (Chairman of the Scientific Advisory Committee, Trades Union Congress)

Large-Scale File Maintenance	D. G. Pedder, MA, BA (Radio Rentals Ltd)
Technical Planning of Steel Tube Manufacture	R. G. Hitchcock, BSc, AMIPE (Tube Investments Ltd)
Public Utility Accounting	G. Sherlock, FACCA, ACIS (South Western Gas Board)
Electronic Data Processing in the Nationalized Industries	Dudley W. Hooper, MA, ACA (National Coal Board)

Session 3

Chairman: Sir Walter Puckey (British Institute of Management)

Inventory Control, Accounting and Payroll	A. Bradley, FCIS (Ford Motor Co Ltd)
Production Control by Buying Computer Time	R. B. Baggett (Job White & Sons Ltd) and G. M. Davis, MA (English Electric Co Ltd)
Accounting for Farmer's Sugar Beet Production	J. P. Lawler, CA (Irish Sugar Co Ltd)
Electronics in Banking	Clearing Bankers Electronic Sub-Committee

Session 4

Chairman: Sir John Simpson, CB (Controller, HMSO)

Merchandise Accounting	D. S. Greensmith, MBE, ACIS (Boots Pure Drug Co Ltd)
(*a*) Stores Control and Control by Exception	K. F. Turner, BComm (Rolls-Royce Ltd)
(*b*) Computers for Research and Design	L. Griffiths, BSc (Rolls-Royce Ltd)
Technique for Statistical Analyses of Family Expenditure	M. A. Wright, BScEng, ACGI (National Physical Laboratories)
Government Experience	J. Merriman (HM Treasury)

Session 5

Chairman: Lord De L'Isle and Dudley, VC (President of the Office Management Association)

A Practical Application in Mail Order Business	P. Cotter & H. E. C. Nash (Littlewoods Mail Order Stores Ltd) and P. Shackleton (Elliott Bros (London) Ltd)
The Application of Linear Programming to the Design of Animal Feeding Stuffs	A. Muir, BSc (J. Bibby & Sons Ltd)
Integrating the Procedures of an Insurance Office	K. E. Schang (Trygg-Fylga Insurance Co's Group, Sweden)
The Approach to EDP of a Large User	S. G. Furniss, ACIS (Imperial Chemical Industries Ltd)

Session 6

Chairman: H. J. Furness, FCWA (President, Institute of Cost and Works Accountants)

Analysis of Sales Statistics	C. A. Wilkes, FCIS, ACWA (Imperial Chemical Industries Ltd)
Wages Accounting	W. H. Sargent (British Railways Western Region)
Industrial Mathematics	D. Owen (United Steel Co Ltd)
Electronic Data Processing	A. J. Brookbank (Glaxo Laboratories Ltd)

Book Reviews

Synchronous Motors and Condensers. *By D. D. Stephen.* $8\frac{1}{2} \times 5\frac{1}{2}$ *in* (216 × 140 *mm*). *Pp ix* + 500. *Illustrated. Index.* (*London: Chapman & Hall*, 1958.) Price 60s net.

This is the sixth of the series of advanced engineering textbooks produced by the specialist staff of The British Thomson-Houston Company, of which the author is a prominent member.

The title of the book indicates that the author is *not* concerned with synchronous machines in general; he does not deal with synchronous generators but confines himself to the synchronous motor range, of which the synchronous condenser is the lower limit.

On the dust-cover it is claimed that the book is intended mainly for plant engineers, power system engineers, and postgraduate engineers. The book is certainly not for the undergraduate, who, in his strictly limited time, would find the mass of industrial detail presented quite overwhelming.

In the first general chapter, the different types of synchronous motors are classified, and some guidance is given on the factors which should influence the choice of a particular type for a particular application.

The next chapter deals with steady-state characteristics, starting from the traditional semi-graphical approach and developing it to the two-axis theory. Anyone reading in this field for the first time will not find this satisfactory; the author throughout has assumed the reader to have had previous knowledge in this field.

Probably the most useful attribute of the synchronous motor is that it can be used for power-factor improvement. Chapter 3 deals with this aspect in detail; the necessary closed-loop control circuits are treated very well, probably for the first time in textbooks.

Then follows a chapter on transient characteristics, starting from the usual physical description and leading up to the transient two-axis equations and the corresponding circle diagram, stability criteria, and limits. These are carried through to practical engineering aspects. Chapters 5, 6, and 7 are lengthily exhaustive treatments of starting characteristics, starting methods, and starting schemes, well illustrated by test-bed results, and a wealth of engineering detail. They give the reader, perhaps, an over-emphasized picture of the starting and synchronizing difficulties inherent in these machines.

The next two chapters deal with machine failures and methods of prevention; the account of protective measures is quite detailed and complete.

Chapters 10 and 11 will be invaluable to the plant engineer who is considering the installation of a synchronous motor. The various applications are considered, as are the factors influencing the selection of suitable motors and control equipment. These chapters are evidently the results of long industrial experience.

The final chapter deals exclusively with the synchronous condenser and those particular theoretical and operating aspects which are markedly different from the normal synchronous motor. It will, in the main, be of interes tto the power system engineer.

There are some points of criticism, *e.g.* the use of non-standard symbols (KVAR), voltage reference directions carrying arrow heads at both ends, practical mechanical units (lb/ft², cycles/min), etc. The theoretical treatments presuppose the reader to have some previous knowledge of the subject. Many of the graphical characteristics have too much detail on them and some of the diagrams are not readily followed from the brevity of the explanations given in the text. On the credit side the book is practically devoid of any misprints.

Summarizing, the book has a wealth of engineering detail which will commend itself mainly to the plant engineer and to the power system engineer; it is not likely to be used in postgraduate research schools for its basis is more practical than analytical.

J. E. PARTON

Network Synthesis. *Vol I. By David F. Tuttle, Jr.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xv* + 1175. *Illustrated. Index.* (*New York: John Wiley; London: Chapman & Hall*, 1958.) Price 188s net.

Primarily this is a textbook for college and university graduate course students, but its comprehensiveness and detailed presentation make it also an attractive reference work for all those electrical engineers who are largely concerned with stationary network theory. In the context of the book, 'network' means 'a passive electric circuit composed of lumped, linear, constant elements with the three fundamental properties: resistance, inductance, and elastance'. The present volume is confined to a study of two-terminal (or one-terminal pair) networks, and it presents the principles of synthesis of networks in which steady-state behaviour as a function of frequency is of major importance. The study of four-terminal (or two-terminal pair) networks is reserved for Vol. II.

Chapter 1 is briefly introductory and Chapter 2 discusses network elements and their behaviour. Chapter 3 is on the complex frequency variable and provides the basic mathematics of function theory. Chapter 4, a consideration of energy, brings to the fore the concept of positive reality of functions through the medium of energy and power *analysis*. Properties of driving-point immittance functions are discussed in Chapter 5 (and later in 8). Chapter 6 deals with the non-dissipative (L-C) one-terminal pair, and Chapter 7 with the R-C and R-L one-terminal pairs. These are the chapters at which synthesis is first carried out, the previous chapters really being analytical in character as a preparation for the subsequent prime purpose of the book.

Chapters 9 and 10 relate to the R-L-C one-terminal pair, and in particular they show that positive reality is sufficient (and necessary) for realizability of driving point immittance functions, and that realization can be obtained with only one resistor, and they describe methods of realization of immittance functions. Chapter 11 gives a few specific applications of one-terminal pairs, while Chapter 12 discusses some of the practical difficulties that can occur in network synthesis, that is, in making the network perform properly. Chapter 13 deals with the approximation problems that arise in network synthesis when the given data are in non-realizable form and describes some of the methods available for achieving acceptable results. Chapter 14 is on the potential analogy, and it exploits the analogy between complex-variable theory and two-dimensional potential theory, using for the latter the physics of the two-dimensional electrostatic field as the analogue guide. Chapter 15 presents three examples of network synthesis illustrating the application of the principles and techniques laid down in the preceding chapters.

There are three appendices relating respectively to computation, the function $F_o\left(\frac{\omega}{\omega_o}\right)$ used in computing the real or the imaginary part of an immittance function from the other, and an extensive bibliography. The book is completed by a good index.

Each chapter is concluded with a list of numerous problems set to test the reader's progress through the book.

The book is based chiefly on standard network theory and it assumes a reasonable knowledge of circuit analysis and some familiarity with the complex frequency variable. While there is a considerable mathematical content to the work—as indeed it demands—this does not exceed the standard necessary for handling ordinary network problems, which includes the calculus and operational methods at no more than intermediate level.

This, in our view, is a splendid book. It is extremely well written in a clear and logical manner and it is well towards the top of the list of first-class works on network synthesis. The author has placed a vast body of students and teachers in his debt for such a thorough and painstaking piece of work—one of the best that has come our way for some time.

The printing and format of the book are, of course, beyond criticism. Even by the publishers' own standard the illustrations are exceptionally well done; the field diagrams in the chapter on the potential analogy are a sheer delight.

S. AUSTEN STIGANT

Notes on Analog-Digital Conversion Techniques. *Edited by Alfred K. Susskind.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp x* + 410. *Illustrated.* (*New York: John Wiley; London: Chapman & Hall*, 1958.) Price 80s net.

This book has developed from two one-week Special Summer Programs on Analog-Digital Conversion Techniques held at MIT during 1956 and 1957 with the object of presenting to systems and design engineers an orderly survey of the theory and design of analogue-digital conversion devices. Very evidently the book serves a most useful purpose by discussing the problems that arise when digital equipment is linked

with physical systems, since the 'language' of the two is quite different. That of information-processing equipment is digital whereas system communication is nearly always by electrical signals or mechanical displacements representative of the physical parameters concerned. The name *coders* has been given to those devices that perform analogue to digital conversion while *decoders* perform the reverse operation.

The book is in eight chapters, the first being introductory to the remainder and briefly highlighting the principal features of conversion requirements and techniques. Chapter 2 is on Sampling and Quantizing and Chapter 3 gives a survey of digital codes suitable for conversion devices and a discussion of redundant codes that have found practical application. Together with the previous chapter, Chapter 4 provides an introduction to digital circuits, intended as background information for those having no prior knowledge of digital systems.

Chapters 5 and 6 survey the techniques for conversion between analogue quantities and their digital representation. The first of these deals with the techniques applicable where voltage is the analogue quantity, while the second is concerned with the techniques used where mechanical displacement is involved. Chapters 7 and 8 constitute 'case' studies. They deal with a digital data-reduction system for evaluating (military) fire-control performance, describing the overall system considerations, the flight test instrumentation equipment, two novel conversion devices, and the optical reading techniques of coded patterns. Each chapter is concluded with a list of references but there is no index.

We imagine this book is unique and for that reason, as well as for the clarity and standard of presentation, it should find a wide and ready acceptance by those who work on or with computers and analyzers in research laboratories or industrial establishments and where there is a regular need for digital-analogue and analogue-digital conversion.

S. AUSTEN STIGANT

Standard Handbook for Electrical Engineers. *9th edition. Editor-in-Chief: Archer E. Knowlton.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp xi* + 2230. *Illustrated. Index.* (*London: McGraw-Hill*, 1957.) Price 124s net.

This is the ninth edition of an old friend: the publishers tell us that it was first produced in 1907, and that the total issue has reached 250,396 copies. The 2311 pages in this reviewer's copy of the eighth edition are well thumbed (but the excellent paper and binding mean that the volume appears still as good as new).

Obviously it is not expected that the reviewer should read every word in the 2230 pages of the ninth edition. Three courses of action will therefore be adopted. First, a sampling technique; secondly, a list of disadvantageous qualities; and finally a reminder of aspects of the book's solid worth.

In the technical news in Great Britain there has recently been much reference to floor heating by electrical means. We therefore took that field of engineering as our first sampling point.

Here we encountered disappointment. There was certainly no reference at all to this subject in the appropriate section, on space heating: and we could find no cross-reference to guide us elsewhere.

Next, we chose at random the use of materials other than germanium and silicon for semi-conductor use, a subject in which there has been much interest in the last few years. The result was rewarding. The 'transistor electronics' section provides not only an extremely concise and yet exhaustive survey of the most recent work in this field, but (when taken in conjunction with the germanium and silicon rectifier sections in the rectifier references) forms a complete textbook in itself to the whole subject of semi-conductors.

The next dip took us to the high voltage switchgear section. For at least ten years successive CIGRE meetings (as recorded in THE BEAMA JOURNAL) have had before them many papers on the thorny question of the testing of the separate interrupter elements of air-blast switches of such high voltage as, for example, 220 kV, that a number of breaks in series is necessary. The problem facing the supply engineer was: do such tests, on separate units, reflect (when extrapolated) the true behaviour of the complete circuit-breaker? It was to this question that we sought the answer, and we hoped to find references to the 220 kV air-blast circuit-breakers installed at the Grande Coulee Dam plant of the Bonneville Power Administration, working at 10·5 million kVA, and put into service in 1951. (Or, perhaps, notes on the 287 kV air-blast breakers, also with multiple breaks, commissioned at Kitimat, in Canada, in 1955).

We were disappointed. This 1957 edition of the Handbook dismisses the whole subject of air-blast circuit-breakers in less than a page, and mentions only (in one short paragraph) a 138 kV breaker, which is stated to be 'A new development in the United States'.

The section on system stability—a field of great interest in the USSR and in most European countries, and the section into which we next probed for our sample—is a model exposition of the factors involved, in the light of American practice only. The employment of series capacitors, now an essential part of the Swedish and Russian networks, is not mentioned except in passing, and then in a rather obscure manner.

In the section on telephone and telegraph cables we searched in vain for any reference to the transatlantic telephone cable, although this was conceived at least five years ago and has been in service for something approaching two years.

We made a number of other dips, and in most cases we were well rewarded: automation, electronics, lighting; all these sections provided us with up-to-date and exhaustive collections of basic data. In the power station section there was no mention of hollow-cooled alternator windings, a development of great importance.

Turning now to the second section of this review, the basic and fundamental weakness of the book is that it almost completely ignores practice outside the United States. In most, if not all, fields of electrical engineering, work of the most advanced level has been carried out in Europe or the USSR in recent years, and there is scarcely a single reference in the extensive bibliographies to the numerous and most important papers produced by such bodies as the Institution of Electrical Engineers.

In so many fields, practice in the United States lags behind that in the rest of the electrical world, and the book reflects this situation. If yet another example were needed, the 400 kV ac transmission systems in the USSR and Sweden, and the dc schemes in those countries, are scarcely mentioned. The highest transmission voltage level discussed is 330 kV. Nowhere is there reference to any other than 60 c/s systems: domestic and industrial voltage levels are always those of America only.

But there are great and solid virtues in this book, notwithstanding its insularity and parochialism. It is probably unrivalled in regard to the comprehensiveness of its contents when looked at from the point of view of basic information. With its aid an electrical engineer dropped, say, by parachute into a completely isolated community in the heart of the Sahara desert could hope to design a complete electricity supply system, including the generating plant, the overhead and underground mains, and the consumers' installations. He could specify and purchase with confidence telephone, telegraph, radio and television equipment, and he could electrify the community's railways and light its streets.

J. H. M. S.

Conformal Transformations in Electrical Engineering. *By W. J. Gibbs.* $8\frac{3}{4} \times 5\frac{3}{4}$ *in* (222 × 146 *mm*). *Pp viii* + 219. *Illustrated. Index.* (*London: Chapman & Hall*, 1958.) Price 45s net.

In the mind of the engineer, conformal transformation is the mathematical tool that enables him to plot field maps and thus to provide a pictorial representation of the physics of what is taking place in machines and structures under stress as a supplementation of purely mathematical calculations. By these maps and from the calculations upon which they are based the engineer then possesses a comprehensive account of both the quantitative and qualitative behaviour of the particular field phenomena under investigation. In some cases this does no more than improve one's mental conception of field structures, but in others the use of conformal transformation is essential to the solution of the problems.

Unfortunately (if we dare say so) most of the solutions to practical engineering problems involve the use of elliptic functions and integrals, as the author points out, and their theory and applications have not, in general, been presented by engineers for engineers in a way to encourage their use. The reviewer has encountered this criticism by engineers on a number of occasions. Dr Gibbs' book, therefore, meets a very definite need, for (*a*) he writes as an industrial machine designer, and (*b*) half the book deals precisely and in detail with the engineering applications of elliptic functions and integrals. And that is just what is wanted.

The first part of the book covers such topics as field equations, complex variables, conjugate functions, conformal transformations, the Schwarz-Christoffel transforma-

tion, and structure configurations with one, two, and more than two right angles. These are the essential preliminaries forming the foundation of the method and providing the means of solving the simpler cases of field mapping. The second part deals with elliptic integrals of the first, second, and third kinds, elliptic functions, double transformations with one or both requiring elliptic functions, and auxiliary elliptic functions. These chapters provide the means for handling the more advanced type of field problem and it is comforting to be told by the author that 'most of the difficulties and complexities confronting the engineer when he tries to tackle elliptic integrals are more apparent than real. Quite often the difficulties are largely associated with nomenclature and terminology. . . .' In the last chapter of the book Dr Gibbs presents a brief conclusion saying, among other things, 'The reader who has been able to follow and understand the problems worked through in this chapter will now be able to attack most of the field distribution problems that arise in practice.' We hope he's right—his industrial experience should enable him to know.

Many practical examples are given in the book and a thoughtful step-by-step study of them will undoubtedly help to bring the reader to the standard predicted by the author.

For the benefit of those who may read this review the following references could profitably have been added to those given.

Electromagnetic Problems in Electrical Engineering. *B. Hague* (*Oxford University Press*).

Electric and Magnetic Fields. *S. S. Attwood* (*Chapman & Hall*).

Electromagnetic Fields—Theory and Applications, Vol I, Mapping of Fields. *E. Weber* (*Chapman & Hall*).

The Effect of Curved Boundaries on the Distribution of Electrical Stress round Conductors. *J. D. Cockcroft*, *JIEE*, Vol 66, No 376, April 1928.

This book belongs to the series of Advanced Engineering Textbooks written by specialists who have had practical experience with The British Thomson-Houston Co Ltd, and it is recommended as an outstanding contribution to an important branch of electrical engineering theory that has been accorded far too little exposition by industrial design engineers.

S. AUSTEN STIGANT

Photosensitors. *By W. Summer.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp xvi* + 675. *Index.* (*London: Chapman & Hall*, 1957.) Price 105s net.

There is such a vast field of scientific and industrial application for light-sensitive devices that it is surprising that no book like this one has appeared before, especially as there exists such an extensive volume of papers and articles on these devices. It is true, of course, that important developments are still taking place as, for instance, in luminous coloured panels for interior decoration, and in silicon wafers for the direct conversion of light to electricity, but none the less an authoritative book covering what is now known was long overdue.

Happily, the gap is now filled by the present work and it can be said that the author has done his task in royal fashion. The extent of this will be appreciated when we say that the book lists 375 uses of photosensitors (the author's term for light-sensitive devices in general) and 2648 papers, articles, reports, books, and patents published in the UK, Europe, and the USA.

The book is in two parts, the first (305 pp) describing the characteristics of photosensitors, their associated circuits and optical equipment, while the second (284 pp) gives numerous examples of their application to various branches of industry and research. We do not propose listing the chapters (there are 29 of them) and it should suffice if we say that, within the limits of a single volume, almost any information required on photosensitive devices and their application can be found in this excellent book. Not only so, but it is authoritative, concise, well documented, and written in a clear and easy style which will commend itself not only to the specialist but also to those searching for a quick answer to a query or a record of what has been done to date in a particular direction. The book is well illustrated, it contains numerous tabular data, and is printed in first-class style on good quality paper.

Introduction to Electromagnetic Fields. *By Samuel Seely.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp xi* + 308. *Illustrated. Index.* (*London: McGraw-Hill*, 1958.) Price 66s net.

The theory of electromagnetic fields is supported by both mathematical and physical concepts and one has almost reached the conclusion that, in modern textbooks, never shall the twain meet—at least within the same covers. The present work deals mostly with the mathematical concepts, being an introduction to Maxwell's equations and field theory suited to 'the needs of the electrical engineering student requiring a sound background in electricity and magnetism'. There is, indeed and unavoidably, a small physics content to the book, but by no means extensive enough as to consolidate the idea of a 'sound background' into a complete and unassailable reality. This is a great pity for, from a knowledge of the author's published work, it is abundantly evident that he could very ably do what is so badly needed. We commend this thought to him for future action on, say, Physical Concepts of the Electromagnetic Field, with mathematics reduced to an absolute minimum.

Chapter headings of the present book are as follows: The Electric Field in Multidimensional Conductors, Static Electric Fields, Conductors-Dielectrics-Capacitors, Energy and Mechanical Forces in the Electric Field, Electric Charges in Motion, The Magnetic Field of Currents in Free Space, Magnetic Effects in Iron, Electromagnetic Induction, Energy and Mechanical Forces in the Magnetic Field, and Maxwell's Equations — Electromagnetic Waves. An appendix gives a Summary of Vector Formulas.

It will be evident from this record that both static and dynamic fields are covered and, therewith, scalar and vector fields with their appropriate mathematics. Emphasis is laid upon the charge as the basic element of field theory and, to provide a unified approach to the subject, the book deals with problems of charges that are stationary in space, in uniform motion, and in accelerated motion. Particular attention is devoted to the concept of energy storage in fields and the relationship to mechanical forces and also to the energy flow concept as the essential background for the study of field operated devices. The clarity of description, the facility of presentation, and the author's obvious scholarship on the subject combine to make this book an outstanding contribution to the pedagogical literature on electromagnetic fields.

The text abounds with illustrative examples of practical applications of field theory and each chapter is concluded with numerous questions for solution by the reader. The text is finely printed and the draughtsmanship of the illustrations is excellent, while the very attractive covers considerably enhance the appearance of the book. The author is Professor and Head of the Department of Electrical Engineering, Case Institute of Technology, Cleveland, Ohio, USA.

YEAR BOOKS

Garcke's Manual of Electricity Supply. *Vol* 55, 1957–58 *Edition.* $8\frac{1}{2} \times 5\frac{1}{2}$ in (216 × 140 *mm*). *Pp xlviii* + 815. (*London: Electrical Press*, 1958.) Price 80s net.

FBI Register of British Manufacturers. $9\frac{1}{2} \times 7\frac{1}{2}$ *in* (241 × 190 *mm*). *Pp* 1138. *Index.* (*London: Iliffe & Kelly's Directories*, 1958.) Price 42s net.

Electricity Undertakings of the World: 'The Red Book'. *Sixty-seventh Edition.* $8\frac{1}{4} \times 6$ *in* (222 × 152 mm). *Pp* 664. *Index.* (*London: Benn Brothers*, 1957.) Price 30s net.

Wireless and Electrical Trader Year Book, 1958. *Twenty-ninth Edition.* $8\frac{1}{2} \times 5\frac{3}{4}$ *in* (216 × 146 mm). *Pp* 372. *Illustrated. Index.* (*London: Trader Publishing Co Ltd*, 1958.) Price 12s 6d net.

Metal Industry Handbook and Directory, 1958. $8\frac{3}{4} \times 6$ *in* (222 × 152 mm). *Pp* 544. *Illustrated. Index.* (*London: Iliffe*, 1958.) Price 15s net.

British Plastics Year Book, 1958. *Twenty-eighth Edition.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp* 816. *Illustrated. Index.* (*London: Iliffe*, 1958.) Price 42s net.

The Practical Electrician's Pocket Book, 1958. $5\frac{1}{4} \times 4$ *in* (133 × 102 *mm*). *Pp* 543. *Illustrated. Index.* (*London: Electrical & Radio Trading*, 1958.) Price 6s net.

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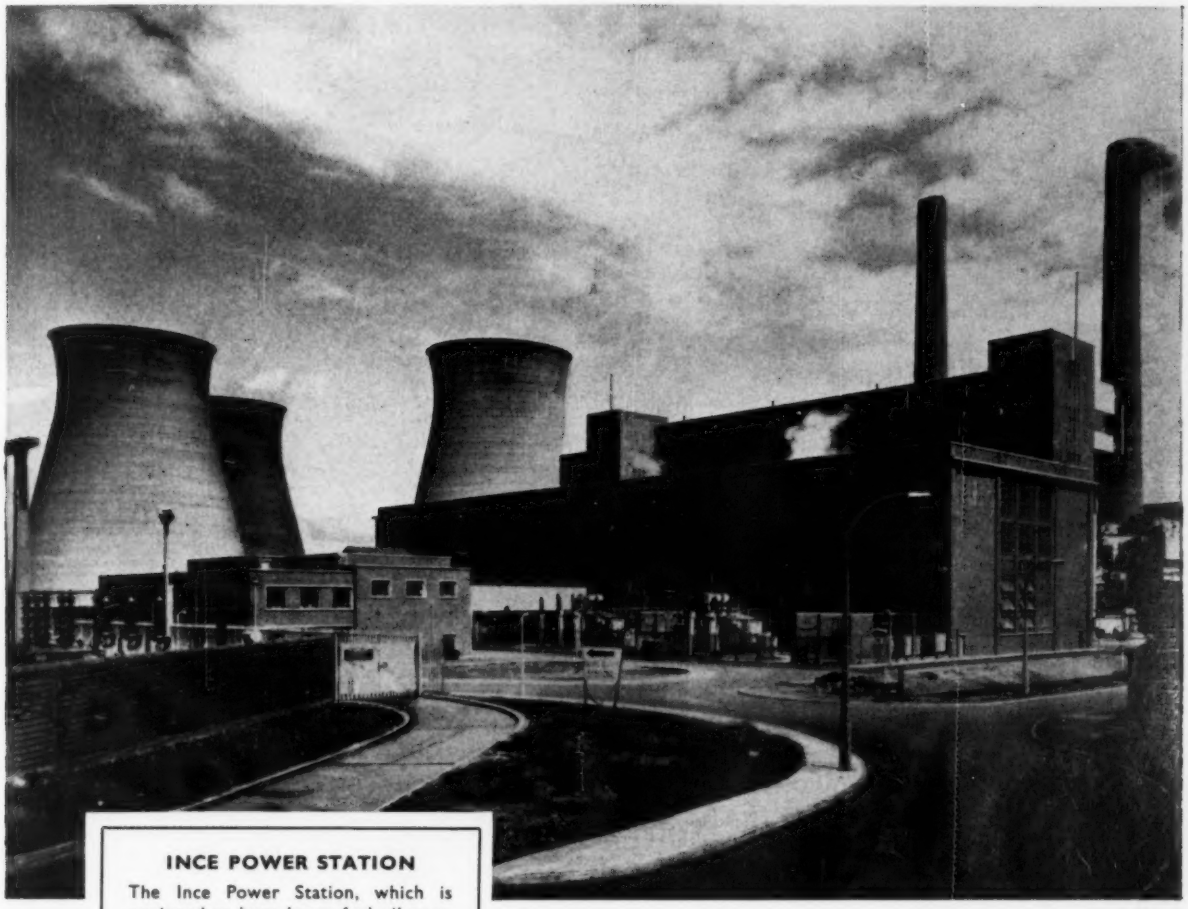

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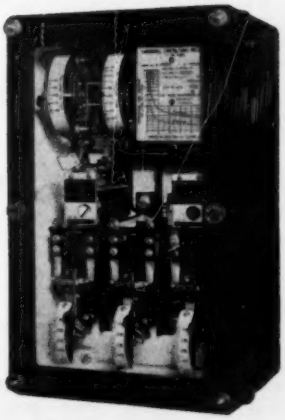

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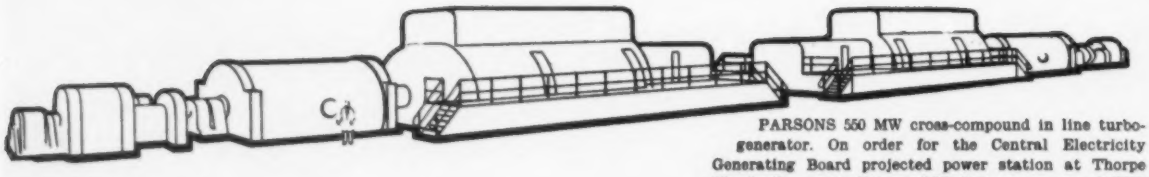

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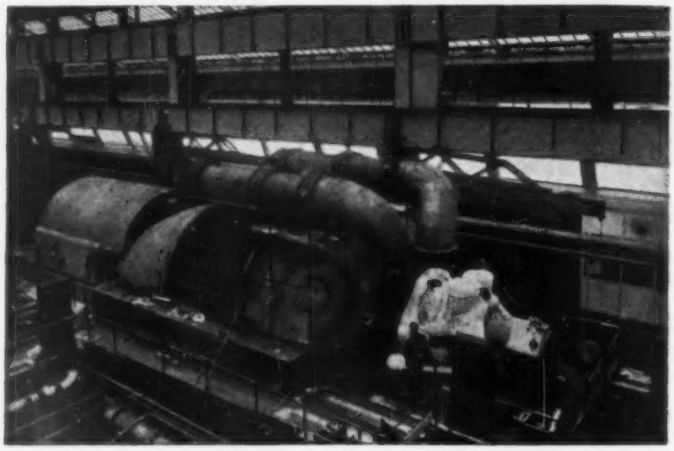

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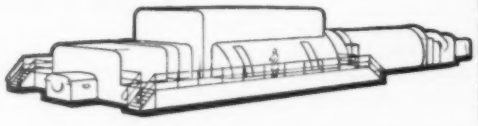

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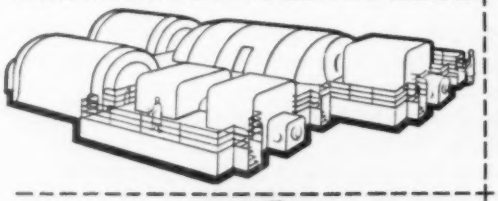

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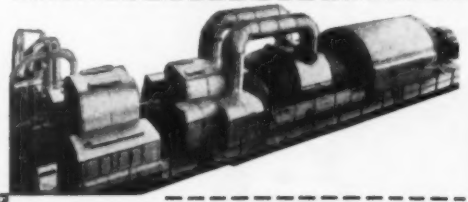

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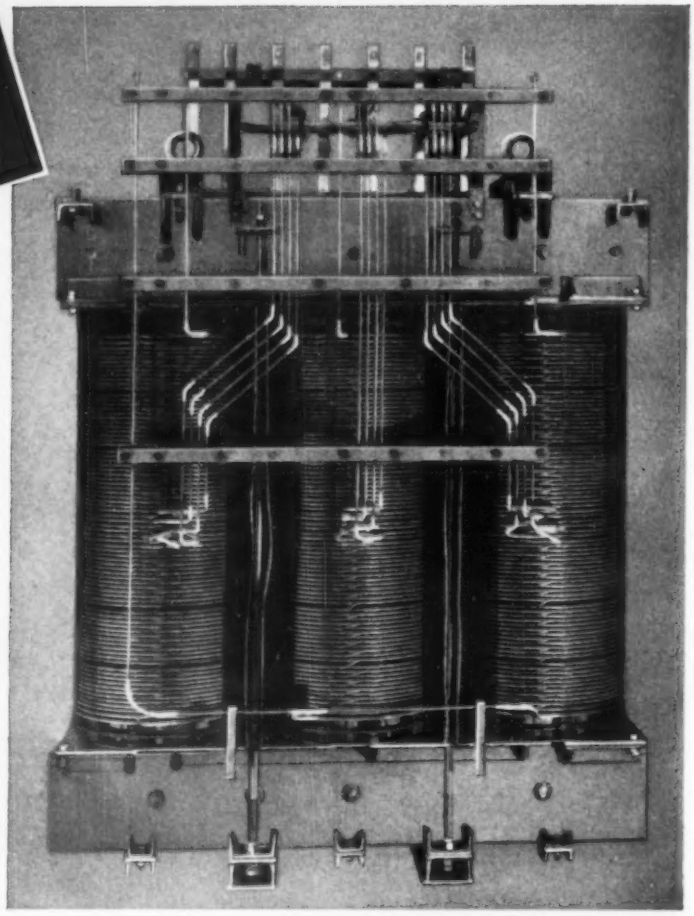

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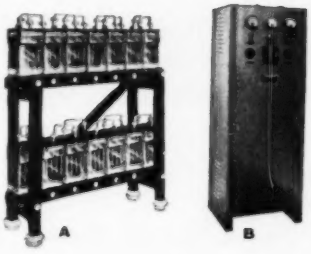

A

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A *Double-tier stand holding a typical battery of 14 Tudor sealed-type cells as used with 'Safetylyte' emergency lighting equipment.*

B *'Safetylyte' Major charging and control cubicle.*

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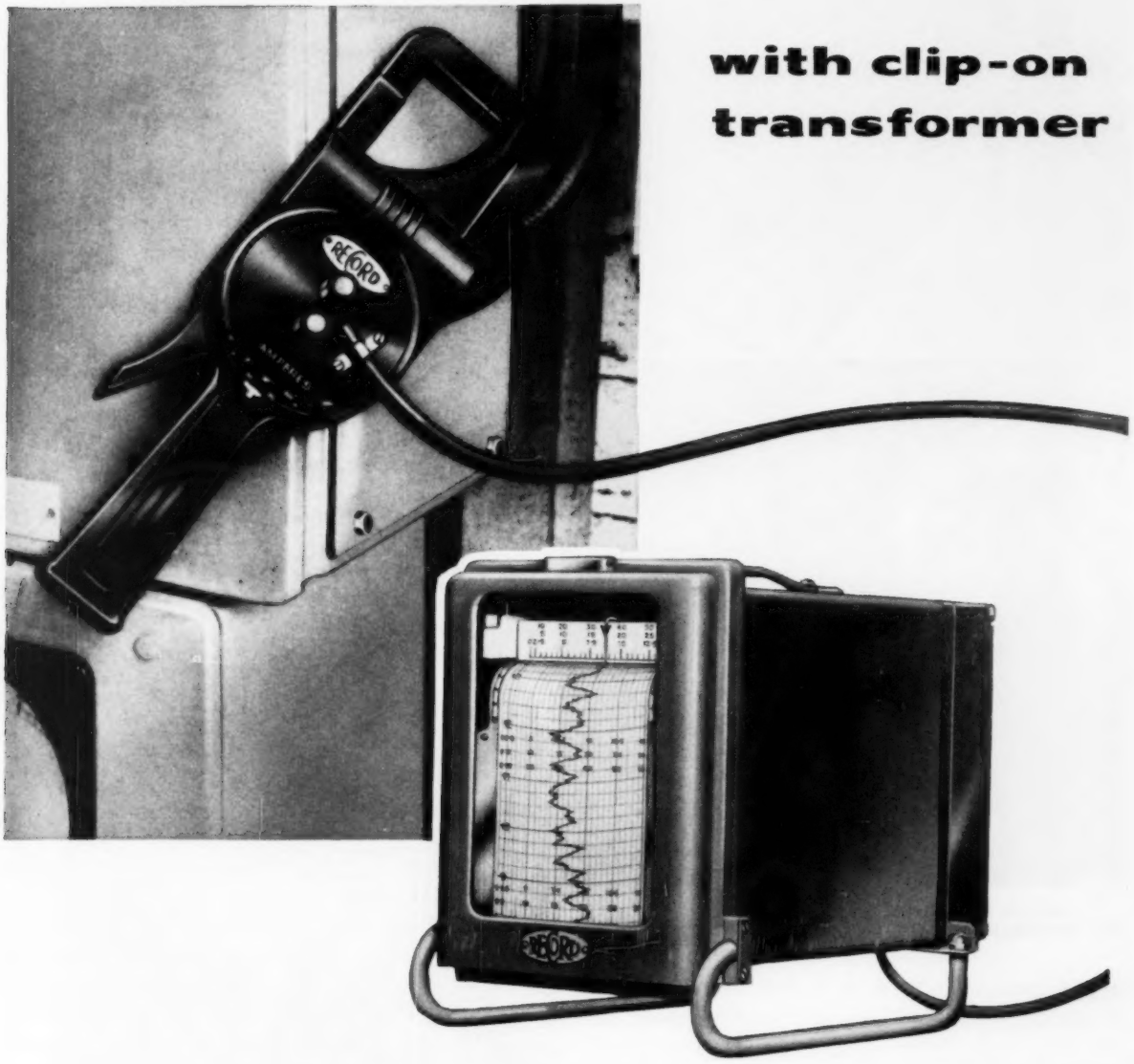

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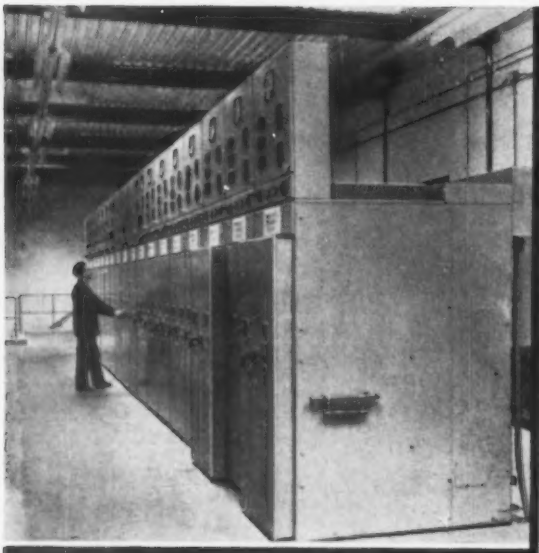

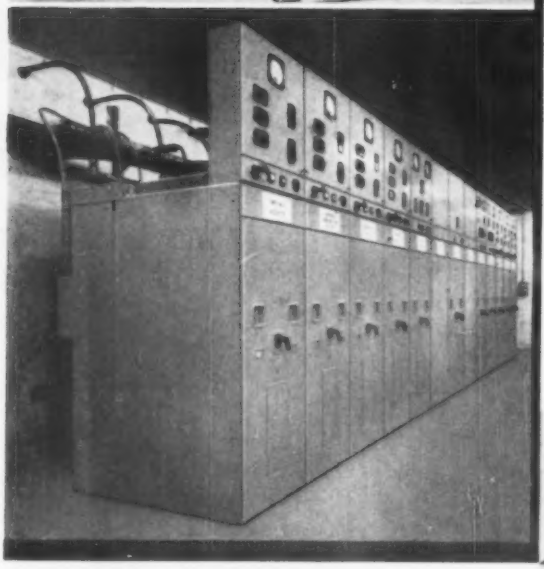

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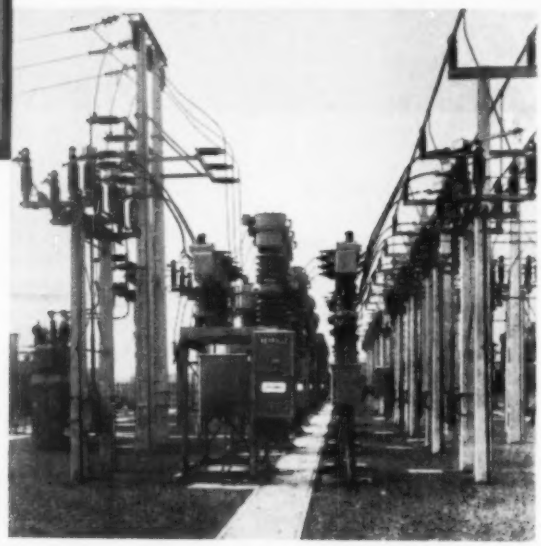

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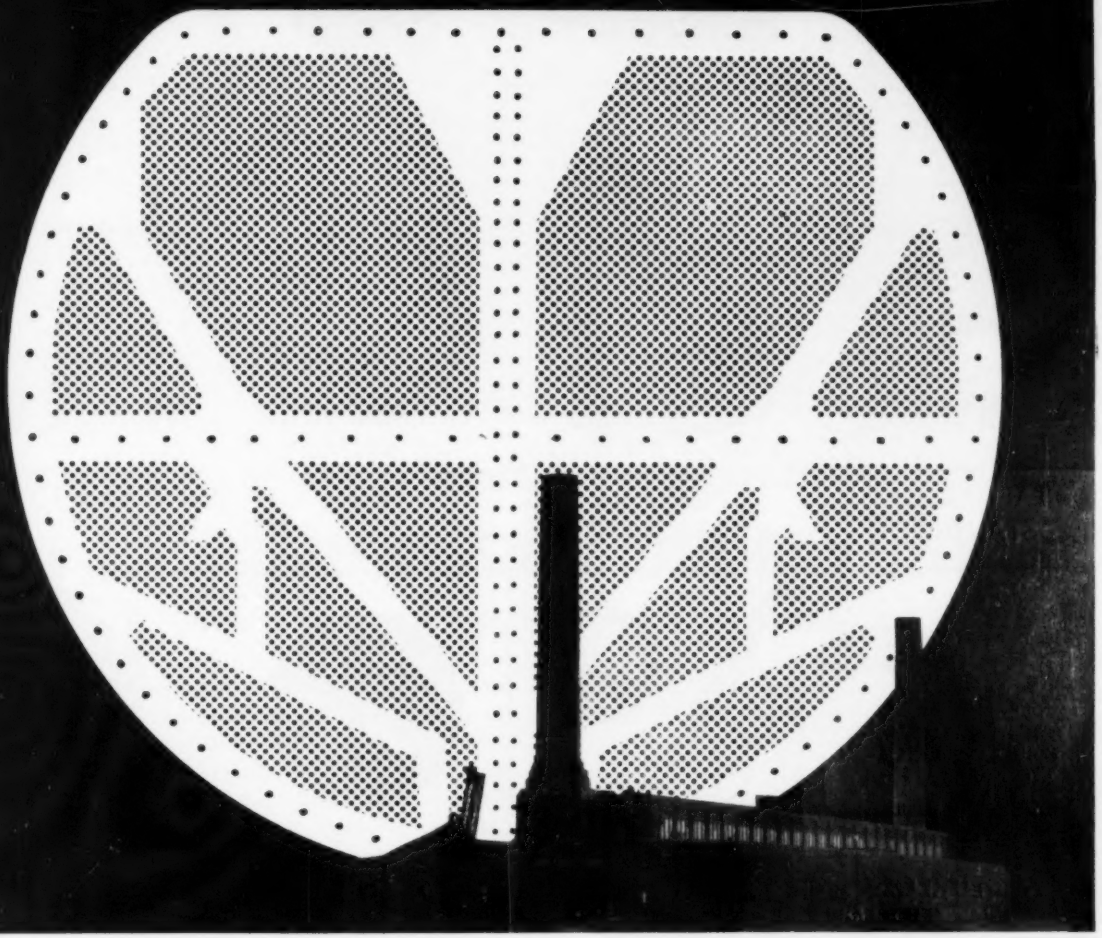

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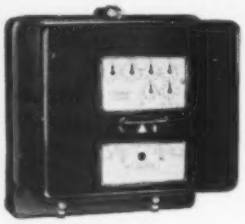

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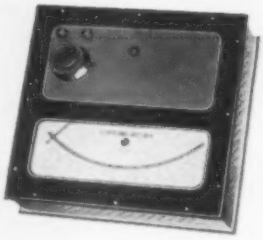

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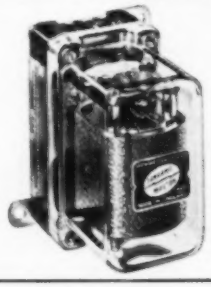

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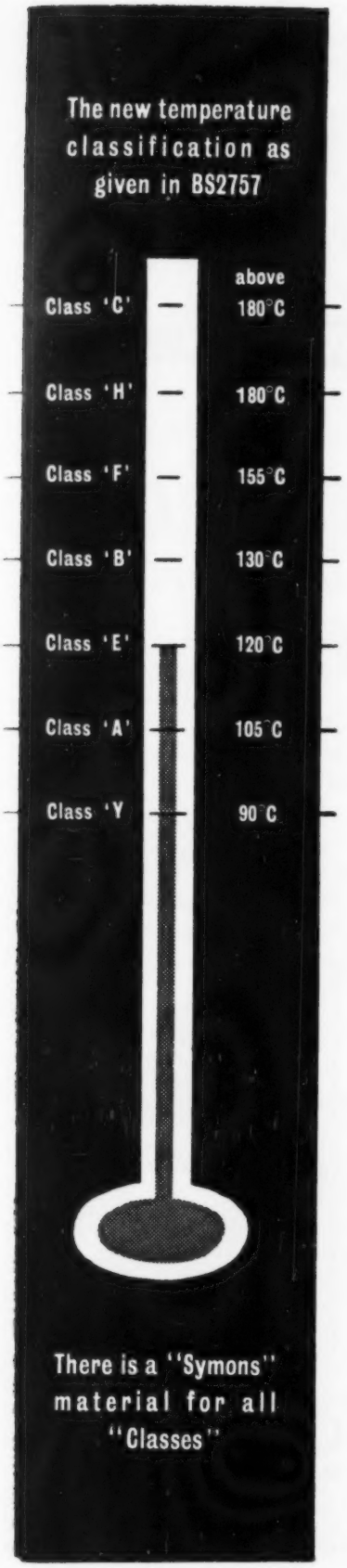

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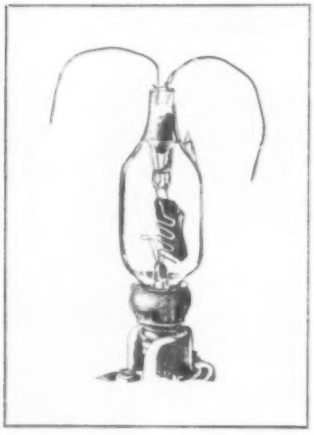

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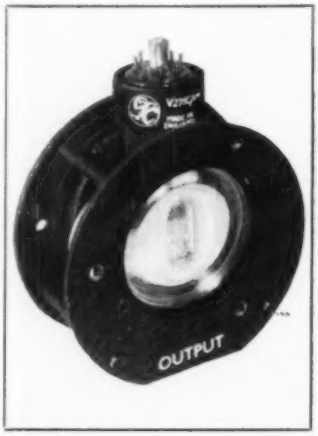

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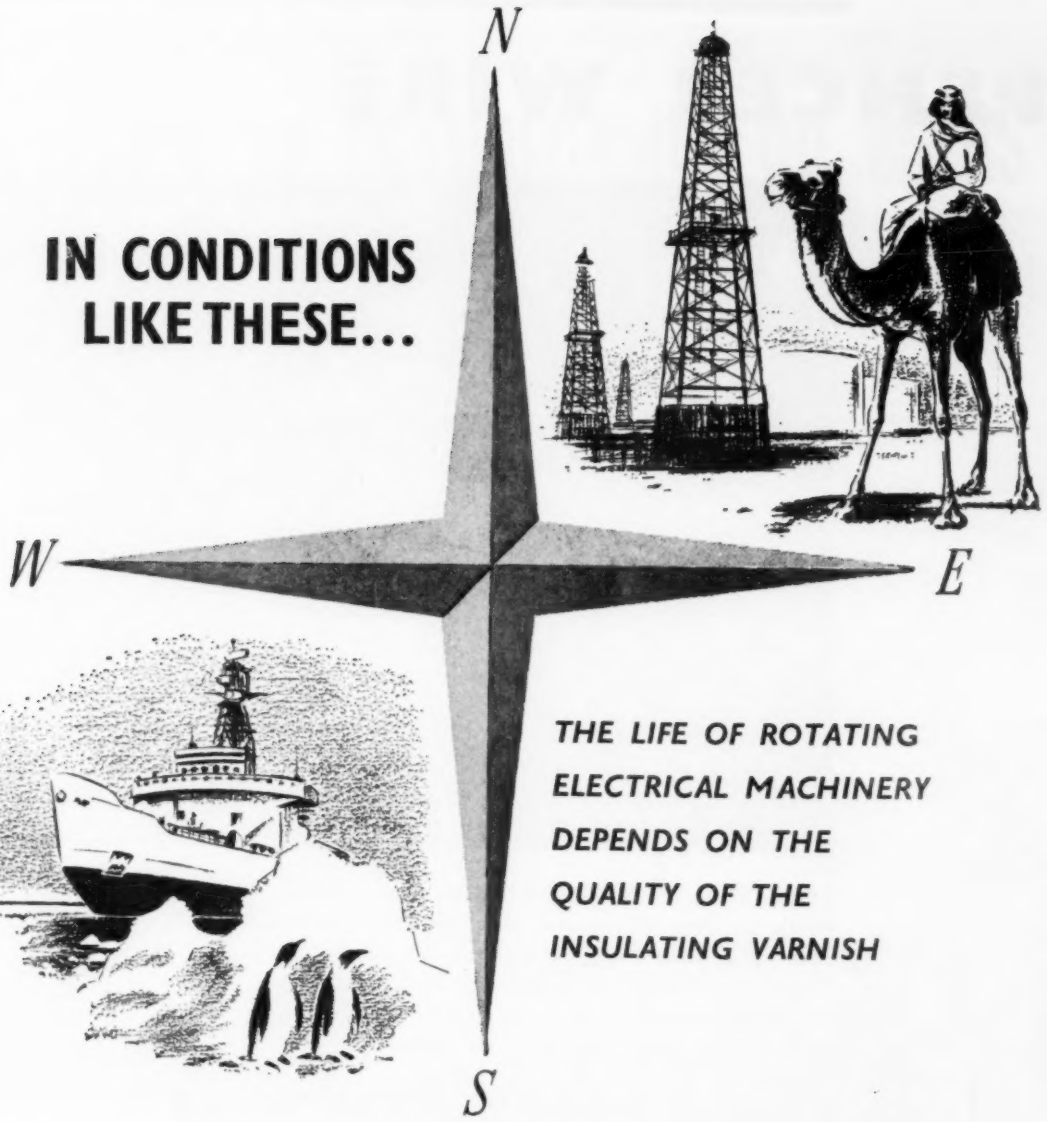

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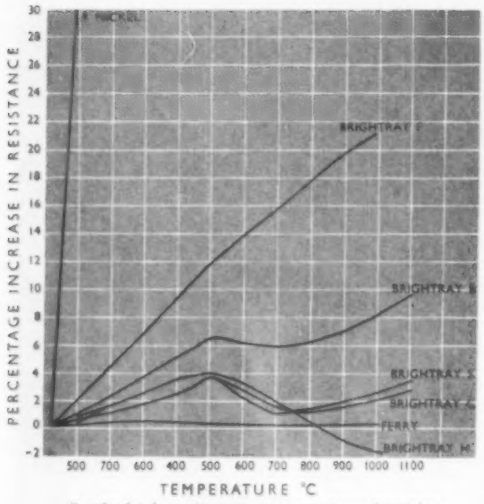
Changes in electrical resistance with temperature —a vital design consideration



Graphs showing resistance/temperature curves for various Wiggin electrical resistance materials.

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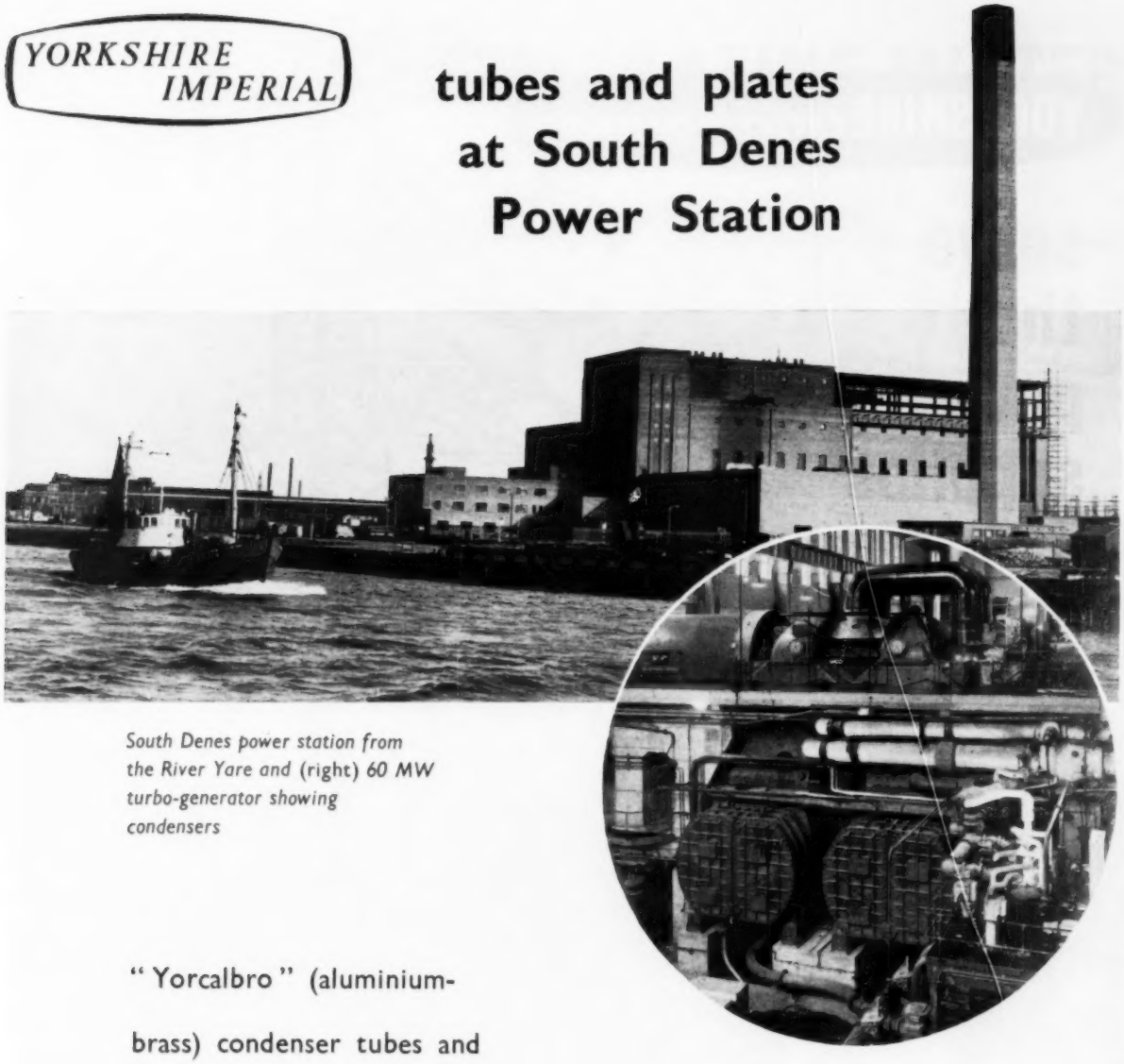
tubes and plates at South Denes Power Station



South Denes power station from the River Yare and (right) *60 MW turbo-generator showing condensers*

"Yorcalbro" (aluminium-brass) condenser tubes and *Yorkshire Imperial* Naval Brass condenser plates are installed at the South Denes (Yarmouth) Power Station of the Eastern Division, Central Electricity Generating Board

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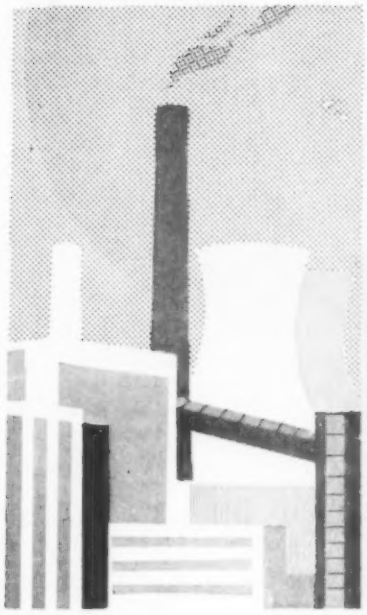

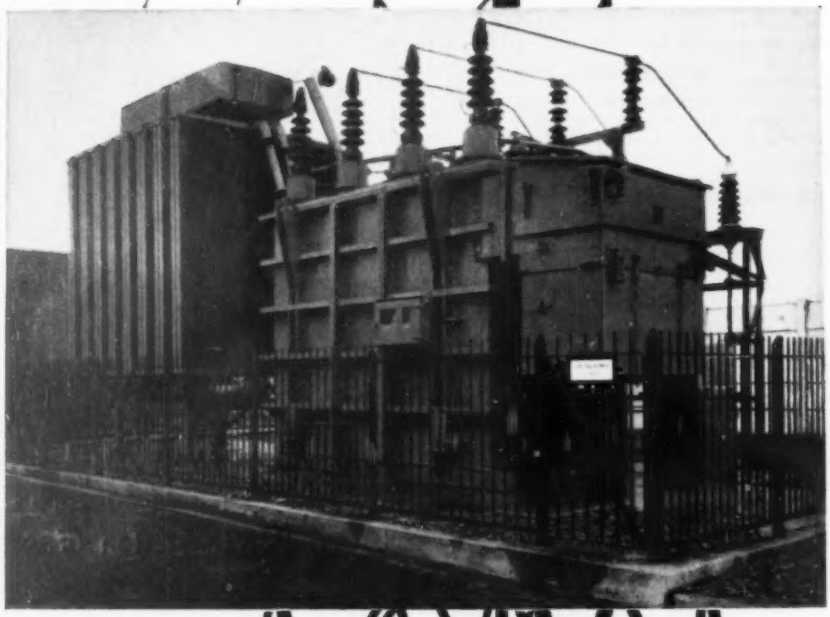

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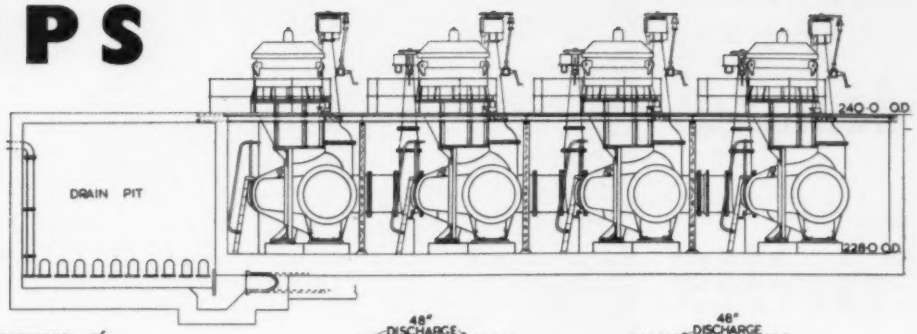
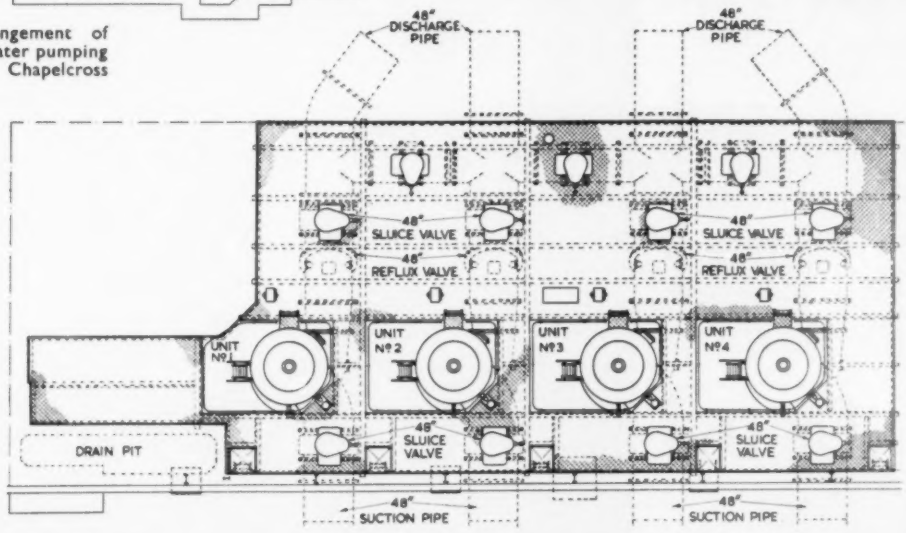
ALLEN CIRCULATING-WATER PUMPS





Installation arrangement of the circulating-water pumping units at the Chapelcross Power Station.

for the

CHAPELCROSS POWER STATION of the UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Consulting Engineers: MERZ and McLELLAN

The installation comprises four Allen 48/48-in. vertical double-suction centrifugal pumps, each designed to deliver 50,000 gallons of water per minute against a total head of 67 feet, running at a speed of 490 r.p.m., and driven by a 1225-h.p. L.S.E. motor.

Allen centrifugal and mixed-flow pumps, horizontal or vertical, are designed to meet all requirements up to the largest capacity units needed in modern power station service.

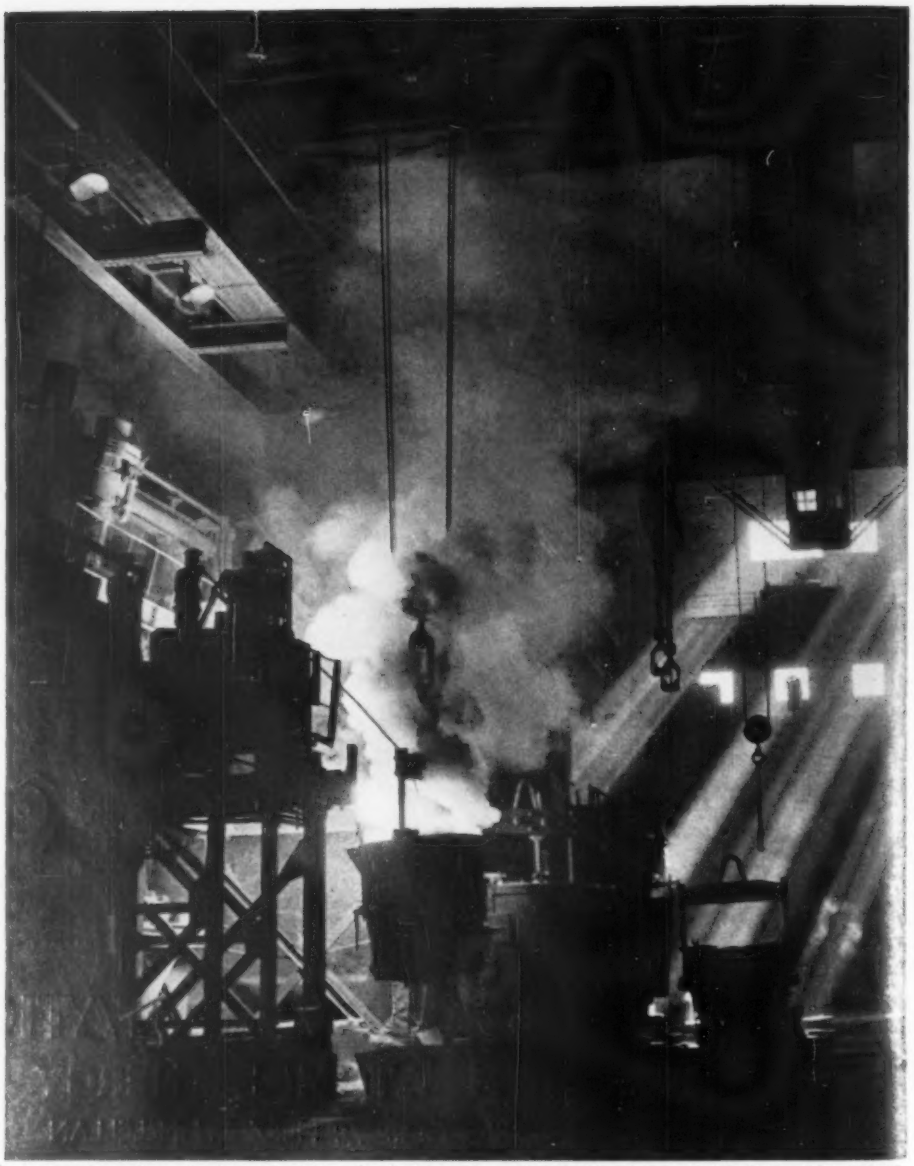
Also for power station pumping applications, Allen-Stoeckicht patented double-helical epicyclic gearing offers a very compact and low-weight speed-reduction or speed-increasing arrangement to suit all powers and speed ratios.

Specialists in complete Pumping Plant installations

W. H. ALLEN SONS & Co LTD

BEDFORD ■ ENGLAND

Industry demands Steel —and Allen West Control Gear



Furnace tapping in the Electric Arc Melting Shop of Messrs. Thos Firth & John Brown Ltd. Sheffield, by whose courtesy this photograph is reproduced.

Whatever the application, for every motor there is an Allen West starter

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* **Designed to B.S. Specification throughout**
* **Complete range—A.C. or D.C. automatic or hand-operated, from fractional to thousands of horsepower**
* **Single units or composite switchboards**
* **Crane Control Gear**
* **All classes of enclosure, from open-type to fully weatherproof**

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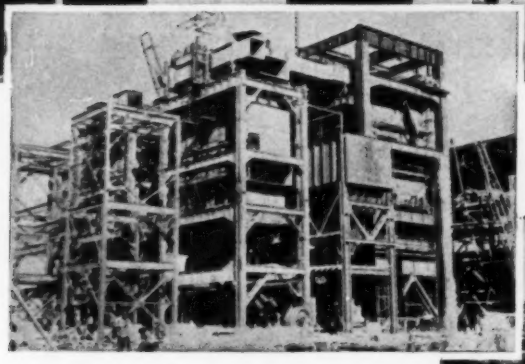
THERMAL POWER *for* NEW ZEALAND



Above and left: Boiler plant during erection at the Mercer power station.

Below: Aerial view of the site on the Waikato river. Fuel will be supplied from the nearby Maramarua coalfield.

In a country where the main source of power is hydro-electric, New Zealand's largest steam power station, now approaching completion near Mercer in the North Island, for the New Zealand Government, is of particular interest.

Being built in one continuous operation, for a capacity of 180 MW, divided between six 30 MW generators, the station is equipped with six Babcock pulverized-fuel-fired Radiant boilers each to supply 300,000 lb./hr. at 635 lb./sq. in., 865 F., in a "semi-outdoor" type installation.

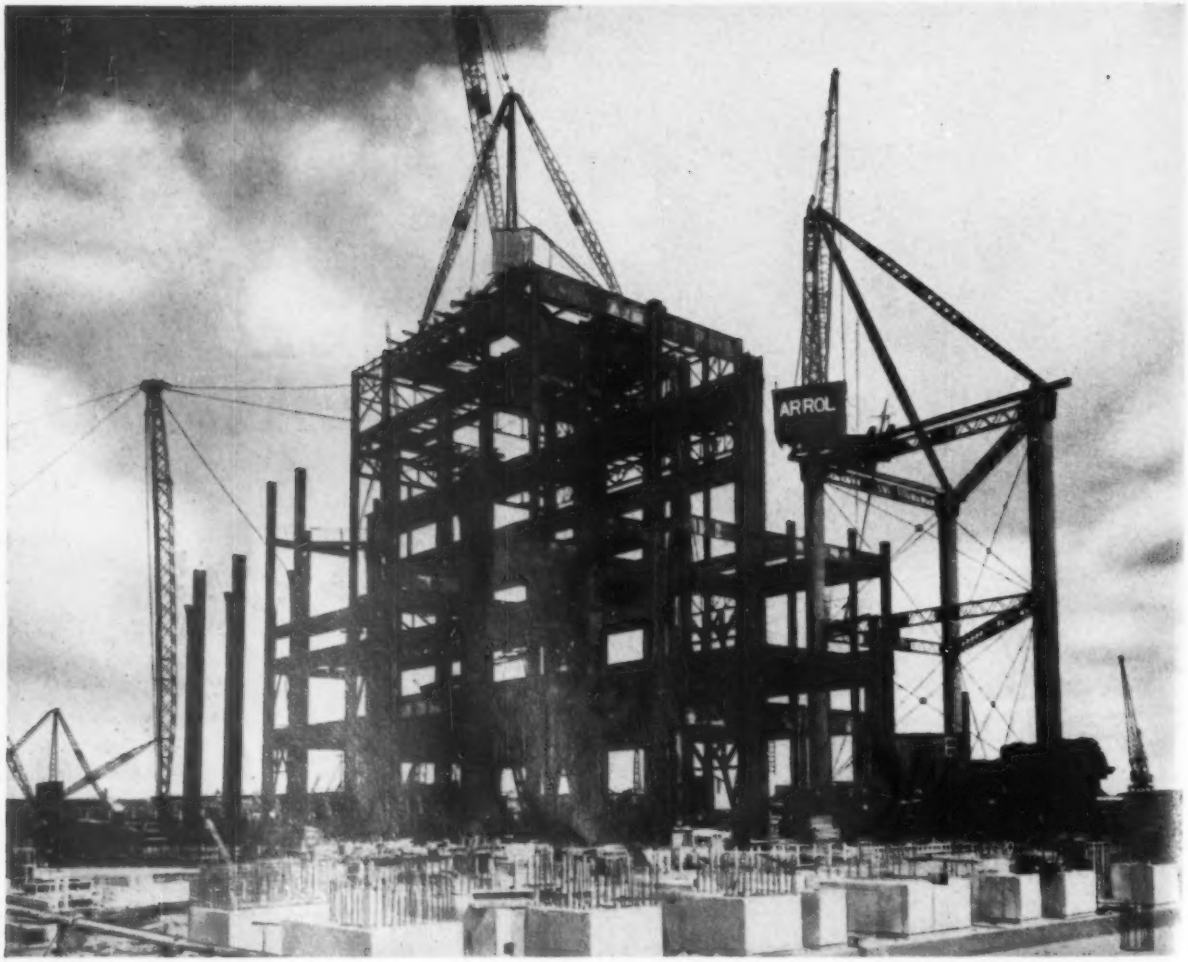
Babcock supplies, in addition to the entire boiler plant, include E-type coal-pulverizing mills, pipework, and the coal, ash and dust-handling plant.

Consulting Engineers: Preece Cardew & Rider.

BABCOCK

STEAM-RAISING PLANT

BABCOCK & WILCOX LIMITED, BABCOCK HOUSE, 209 EUSTON ROAD, LONDON N.W.1



Belvedere Power Station under construction.

Steelwork for Power Stations

Throughout the country steel-framed Power Station structures indicate the close association of ARROL of GLASGOW with Britain's electrical power development. Battersea and others in the London area, Castle Donington in Leicestershire and Braehead at Glasgow comprise a long series now being further extended by the erection of the steel framework of Belvedere Power Station—another of the London group.

All types of Steel Framed Buildings; Fixed and Opening Bridges; Cranes and Mechanical Engineering work; Dock Gates; Sliding and Floating Caissons; Compressed Air Locks; Hydraulic Machinery; Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Projects.

SIR WILLIAM ARROL & CO LTD GLASGOW

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275-kV TRANSFORMERS BY BTH

1951

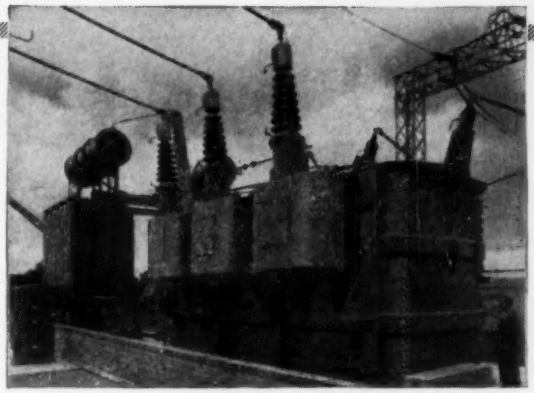
120 MVA UNDER CONSTRUCTION

BTH were first to be awarded a contract for the supply of 120-MVA 275/132-kV transformers for the C.E.A. Super Grid.

1953

120 MVA IN SERVICE

The first 120-MVA unit was commissioned in July 1953. Up to date, ten of these units have been installed or are on order.



120-MVA 275/132-kV transformers at the Staythorpe Sub Station of the C.E.A.

NOW

Another step forward

180-MVA ORDER IN HAND

C.E.A. placed with BTH one of the first two orders for 180-MVA 275/132-kV transformers

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an A.E.I. Company.

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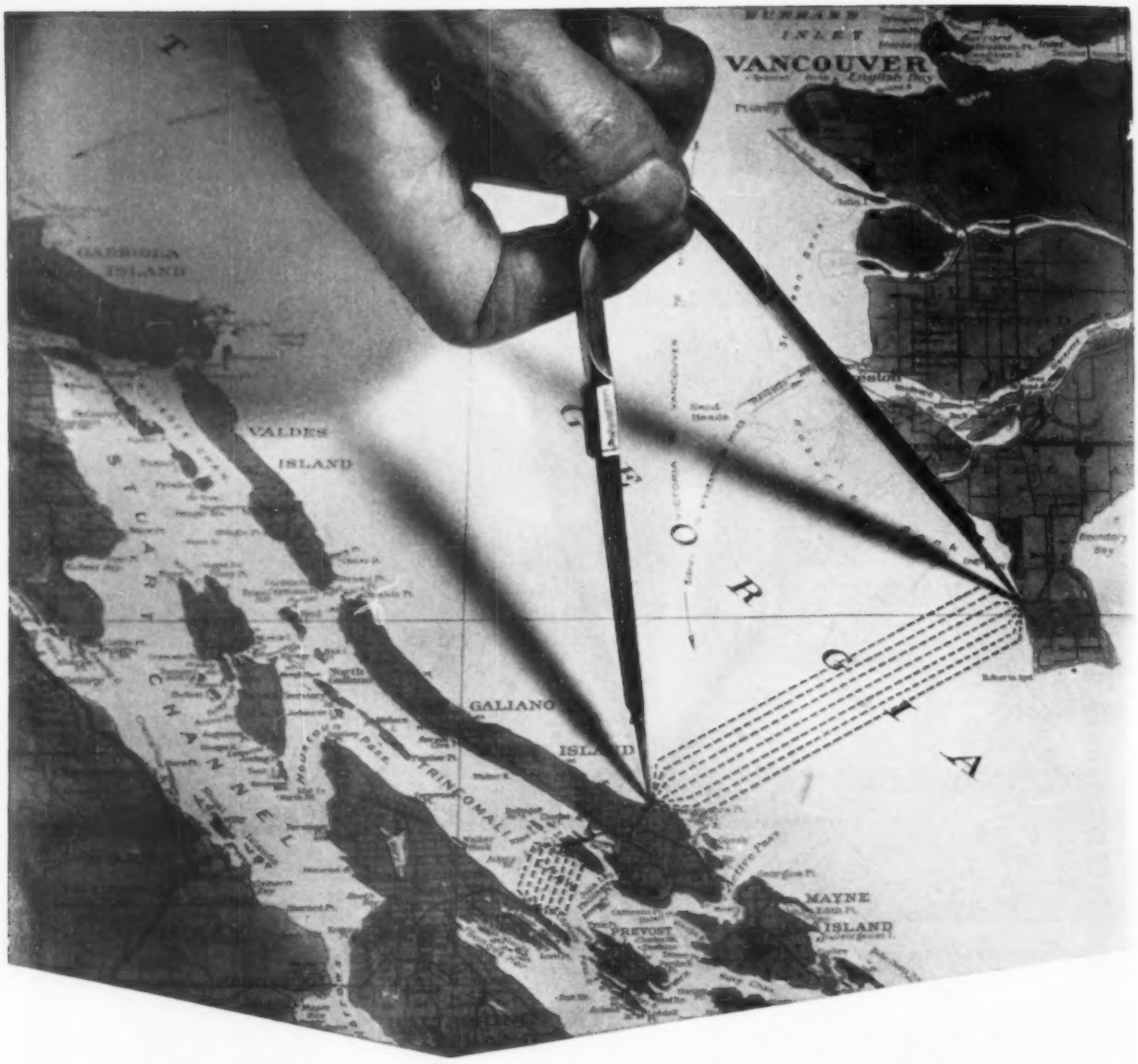

Yet another great power cable achievement!

A second circuit completed in the submarine power link between the British Columbia mainland and Vancouver Island

In September 1956 the first submarine power circuit between the British Columbia mainland and Vancouver Island was put into commission. It had been designed, made and laid by the BICC Group to transmit some 170,000 H.P. of hydro-electric power across the Georgia Strait and Trincomali Channel.

The link proved so outstandingly successful that a year after its commission, almost to the day, the British Columbia Electric Company awarded BICC another contract to supply a second circuit. This is now in service — after less than twelve months!

Altogether more than 133 miles of 138kV single core cable, including seven 16-mile continuous lengths,* have been made and laid by the BICC Group for this great power link, which now transmits 335,000 H.P.

**These cables are unique : they are the longest ever made for operation at such a voltage.*

by the **BICC GROUP**

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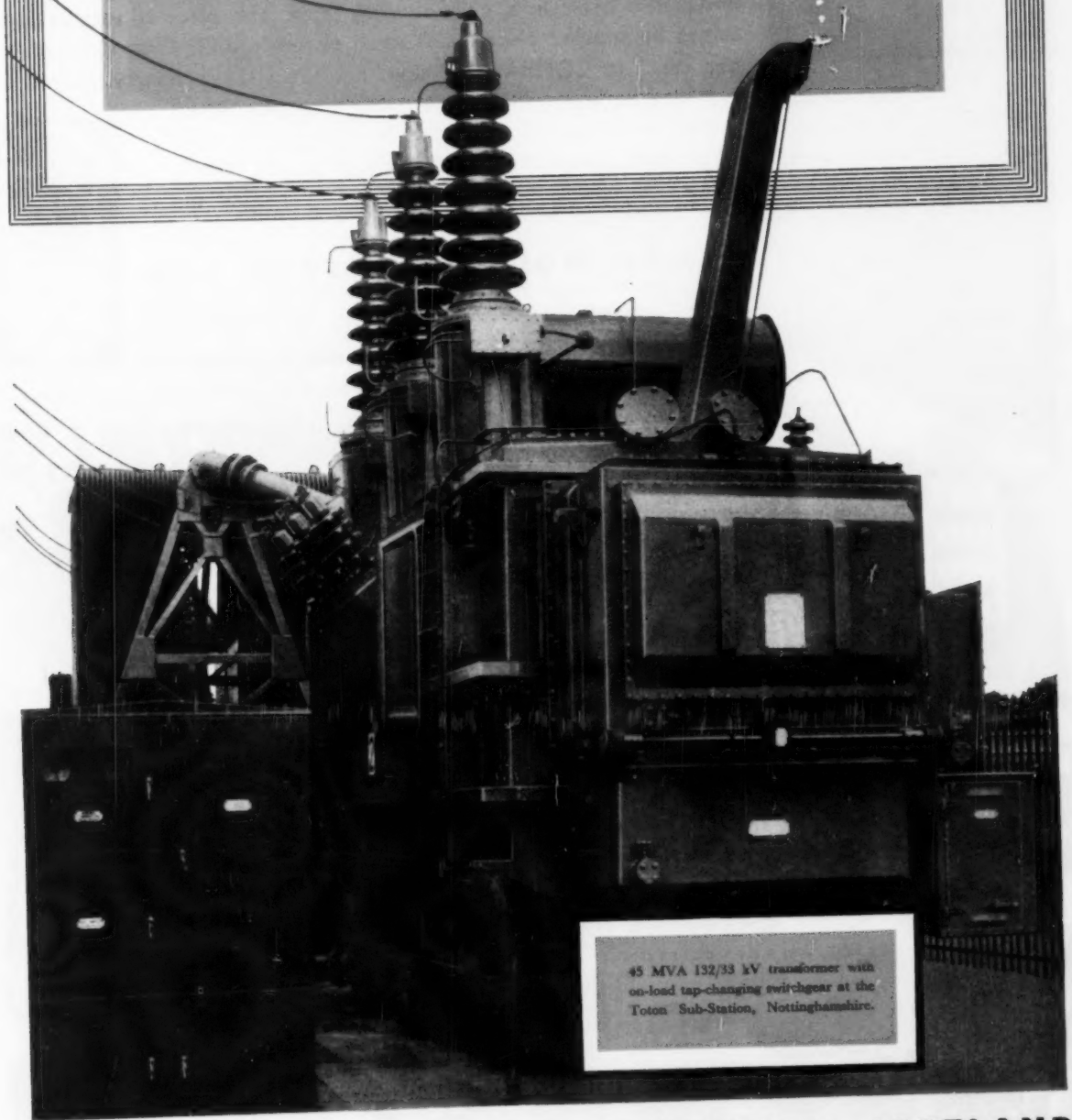
POWER TRANSFORMERS

The tens of thousands of Bruce Peebles transformers in successful operation today constitute a reliable guide in selecting transformers to meet the demands of tomorrow

Bruce Peebles transformers running into millions of kVA in units up to 75 MVA have been supplied for use all over the world and much larger equipments for 275 kV service are now on order.



45 MVA 132/33 kV transformer with on-load tap-changing switchgear at the Toton Sub-Station, Nottinghamshire.

BRUCE PEEBLES & CO. LTD. EDINBURGH, SCOTLAND

A pertinent question to a physicist!

Is the conductivity of copper impaired by the introduction of silver to resist softening when baking, as in the case of **BOLTON'S COMBARLOY?**

Certainly not! You are no doubt aware that the secret of copper's conductivity lies in the fact that it possesses free moving electrons. In simple terms the free moving electron can leave its mother atom and move into orbit in a neighbouring atom, the place it vacates being seized by another electron. A small percentage of silver (0.08 to 0.10 per cent) in COMBARLOY does not affect this property. Indeed the differences in conductivity between different supplies of high conductivity copper are greater than that which results from the addition of this small proportion of silver to any of them. You can rely on BOLTON'S COMBARLOY wherever a cold-worked h.c. copper is needed for electrical purposes.

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CHLORIDE BATTERIES LIMITED

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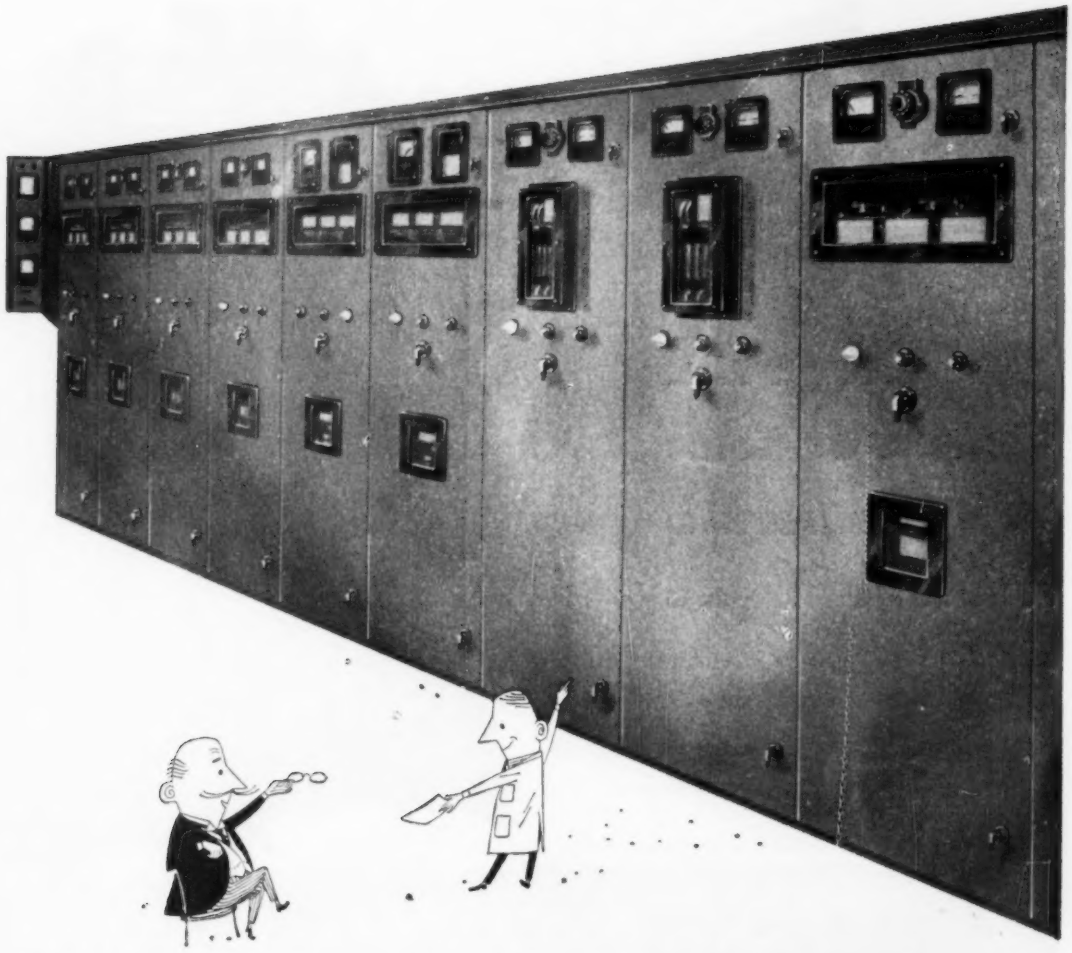

But why buy standardized switchgear?

Well sir, by ordering standardized switchgear from Brush you get better delivery. You get uniform, clean appearance, too. And you get a better price.

You mean it's cheaper to install this standard stuff?

Exactly. No drawing-office time to pay for. And you get the benefit of large-scale production.

Ah. That's all very well. But the important thing is: how well is the equipment going to do the job? Surely, switchgear built to the specification of our own people is likely to be better suited to our needs?

Well, no. That doesn't follow. The thing to remember is that Brush have been in this game a long time. And from their tremendous experience and research they have learnt that most requirements can be met by a few basic designs, with optional additions to meet customers' special needs. And you can take it from me – no finer electrical switchgear comes out of any factory, anywhere.

Mm. What about maintenance?

No problem at all with Brush equipment. It's all so well designed, so beautifully built, so painstakingly tested, that failures are practically eliminated and maintenance is as easy as . . .

You've made your point.
We'll order standardized switchgear from Brush.

BRUSH
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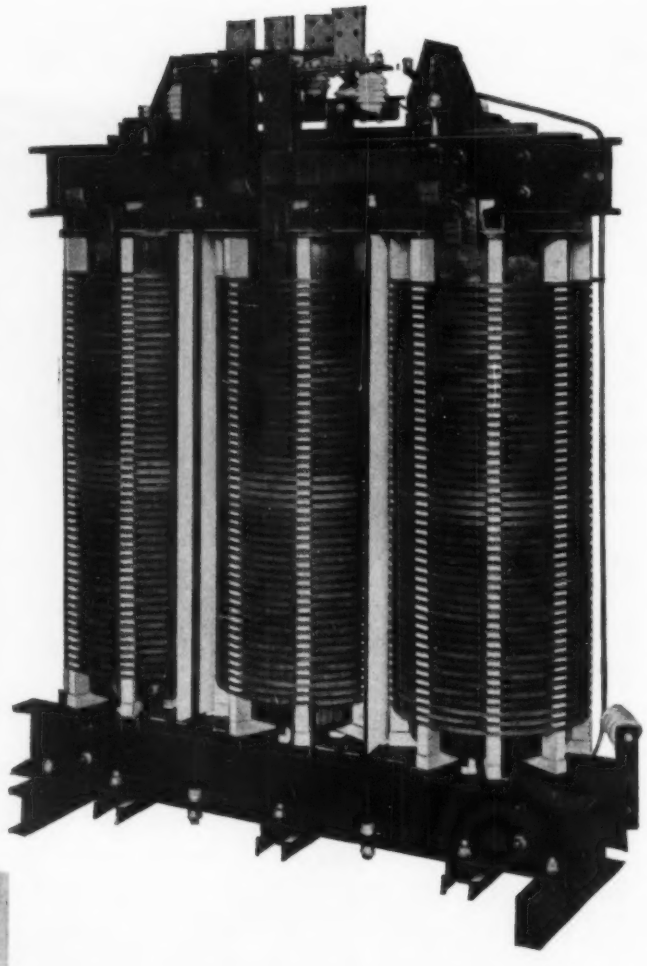
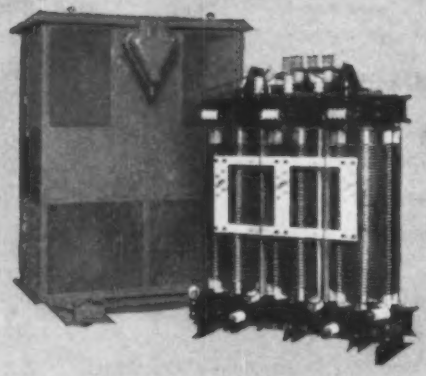
CLASS-C
TRANSFORMERS

SILICONE INSULATION SILICONE INSULATION SILICONE INSULATION





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- No Fire Risk
- Reduced Weight
- Higher Overload Capacity
- Can be installed in damp locations

For any installations where fire risk is high or consequential loss would be considerable, the introduction of the dry type air-cooled Class 'C' Transformer marks another major step in security.

Illustrated is a 1,000kVA, 3 phase, 50 cycles, 11,000/433 volts Bryce Low Loss Distribution Transformer using Class 'C' insulation.

BRYCE ELECTRIC CONSTRUCTION CO. LTD.

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In association with Hackbridge Cable Co. Ltd.

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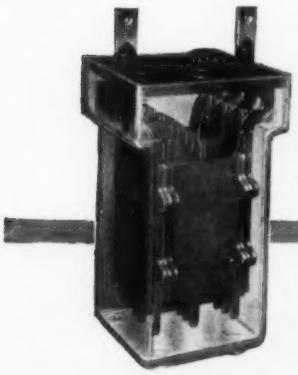
For whatever purpose a stationary battery is required, in any capacity from 10 to 15,000 ampere-hours, there is a D.P. type specially designed to meet the need with the utmost efficiency and economy.



A sealed type 75 Ampere-hour D.P. cell as used for emergency lighting and power stations.

A 10,200 Ampere-hour D.P. cell in a wood lead-lined box.

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The D.P. Battery Co. Limited, Bakewell, Derbyshire. Phone : Bakewell 81

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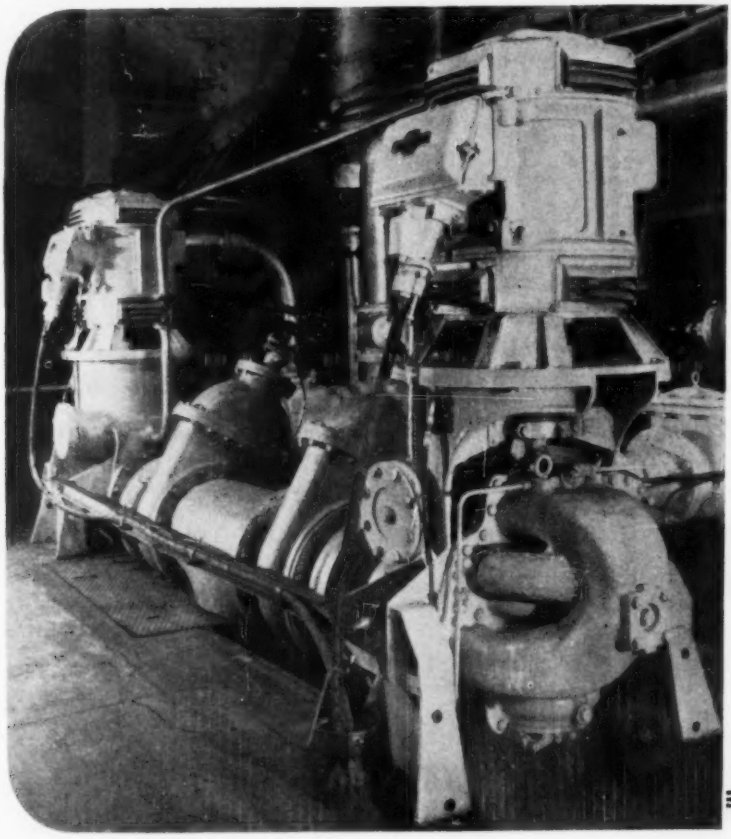

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The Drysdale "Pervac" Pump has been designed for condensate extraction in high vacuum condensing plant where stable operation and high efficiency are fundamental requirements.

The two stage arrangement is eminently suitable for this class of work as the first stage impeller is designed for best possible vacuum, while the second stage impeller deals with external head, and its efficiency is unimpaired by consideration of vacuum.

These pumps are of the Centrifugal Split Casing type and are available in a full range of sizes and capacities in both vertical and horizontal types.

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50 cycle Heating for Larger Billets

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EFCO-TOCCO Induction heating plant

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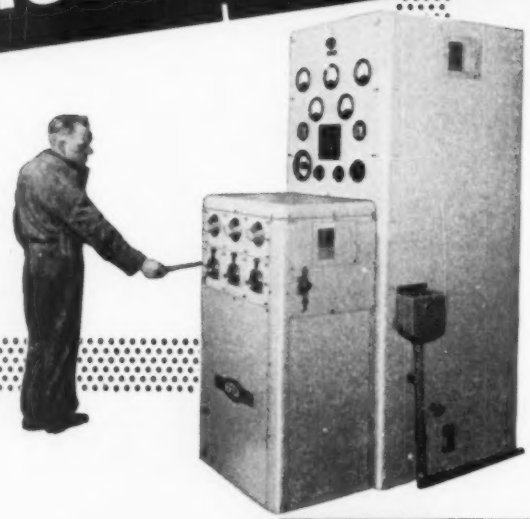
Induction heating prior to forging or forming is economical for both steel and non-ferrous billets and bars. Efco-Tocco offers choice of high frequency or 50 cycle equipment, whichever is most suitable to the metal and dimensions of the charge.

Efco experience and Tocco 'know-how' are at your disposal for all your heating problems.



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H.F. Heating for Small Billets

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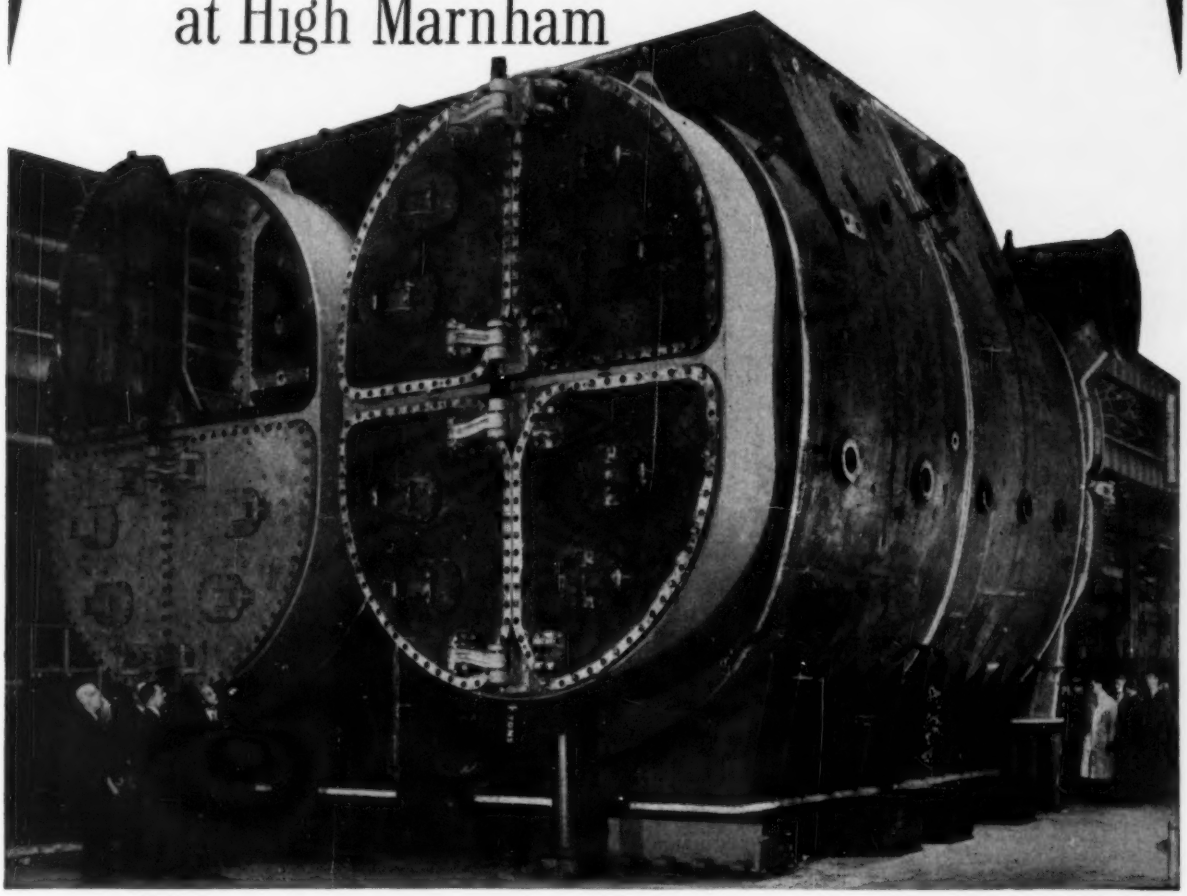
1,000 MW power station

at High Marnham



The condenser for the first of the five 200 MW steam turbo-alternator sets to be manufactured by 'ENGLISH ELECTRIC' being assembled at one of the Company's works. This unit contains 83 miles of tubes and is designed to deal with 400 tons of steam per hour. When completed the 1,000 MW power station at High Marnham will be the largest generating station in Europe.

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Steam Turbine Division, Rugby

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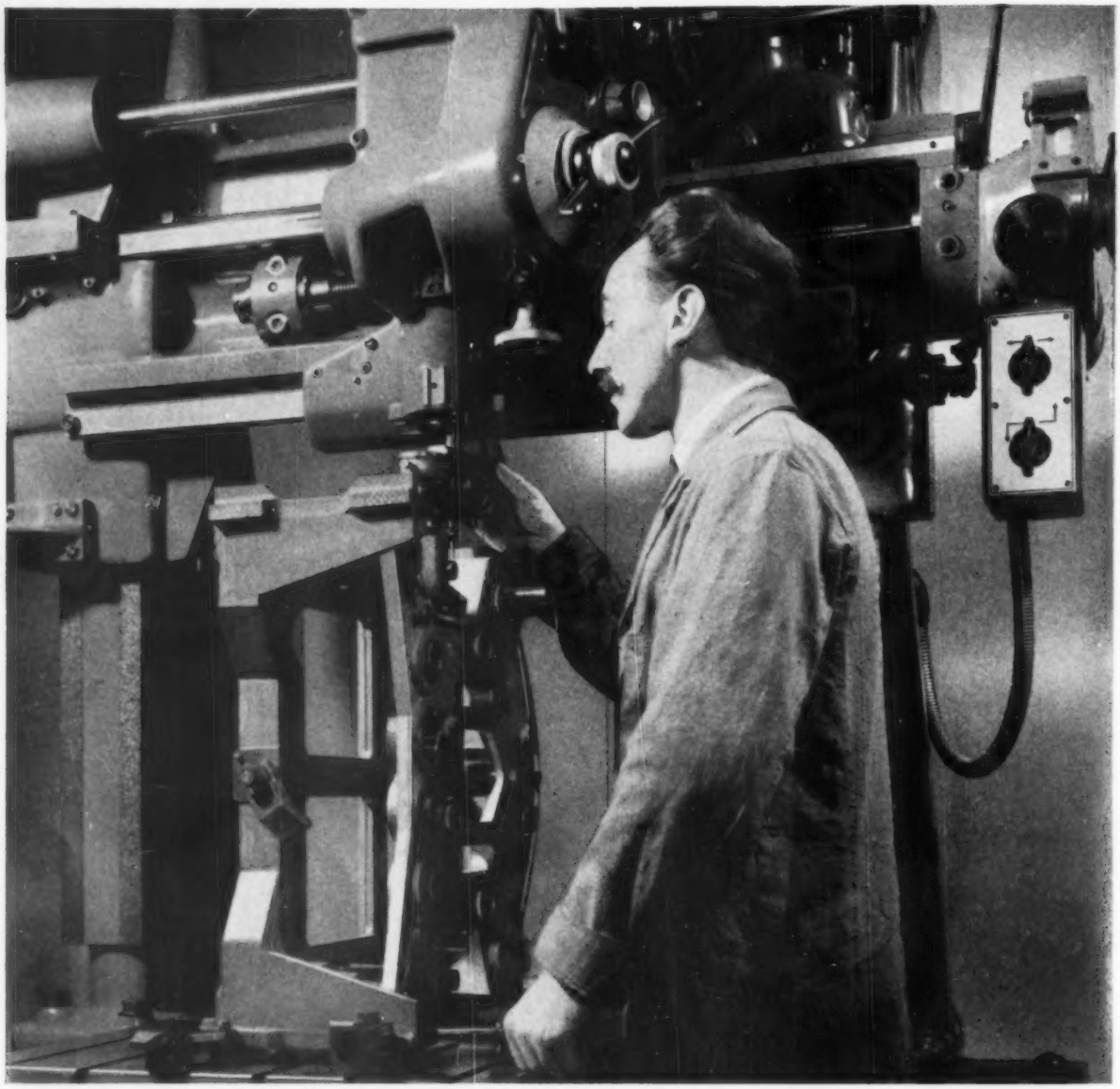

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of FERRANTI TRANSFORMERS
for the NIAGARA POWER PROJECT
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FERRANTI
Ferranti Ltd. have been awarded a contract by the Power Authority of the State of New York to supply thirteen generator transformers for the Lewiston Power Station of the Niagara Power Project situated on the plateau on the Niagara River about 3 miles below the Falls in the town of Lewiston.
The contract covers six 180,000 kVA, 13.2/240 kV 3-phase transformers and seven 180,000 kVA, 13.2/120 kV 3-phase transformers. They will be of the forced-oil, forced-water cooled, inert gas-filled type and each will be directly coupled to a 167,000 kVA 3-phase generator.
Believed to be the largest transformer contract so far placed in Britain by the U.S.A., delivery will commence in the middle of 1959 and will be completed by the end of 1960.
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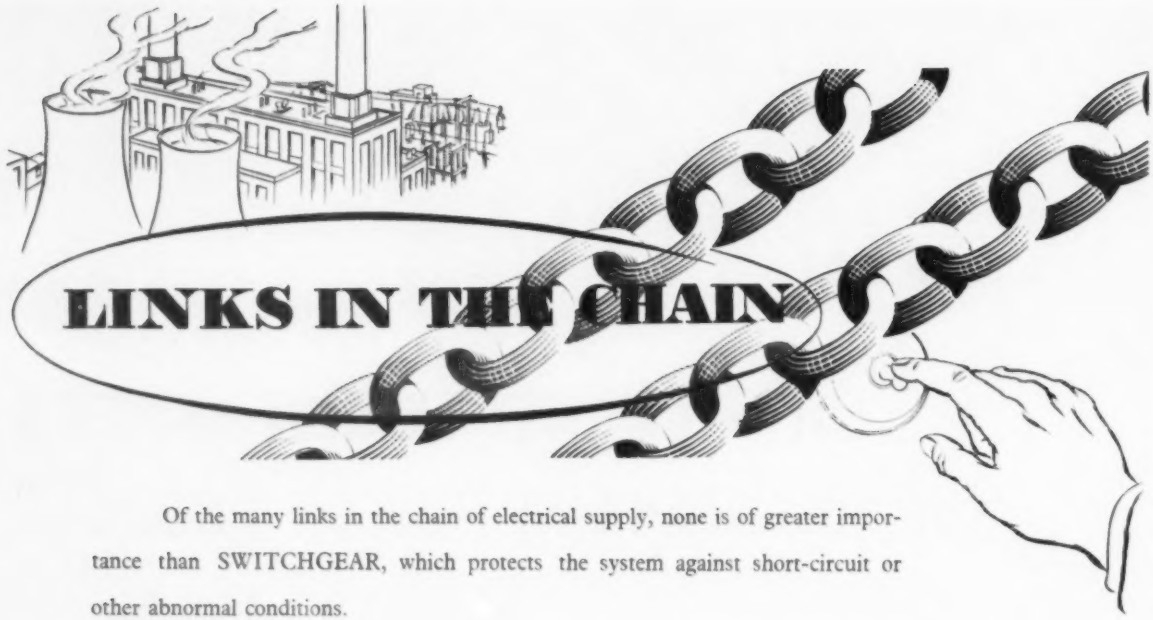

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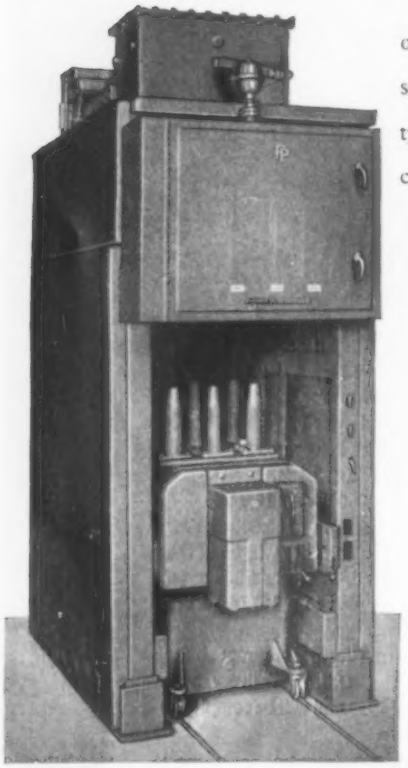
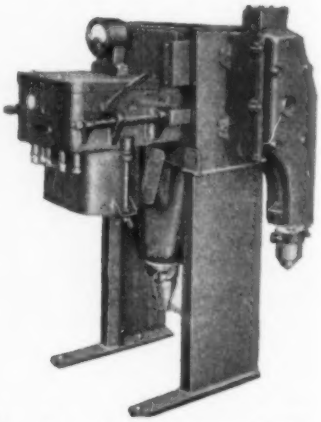
Of the many links in the chain of electrical supply, none is of greater importance than SWITCHGEAR, which protects the system against short-circuit or other abnormal conditions.

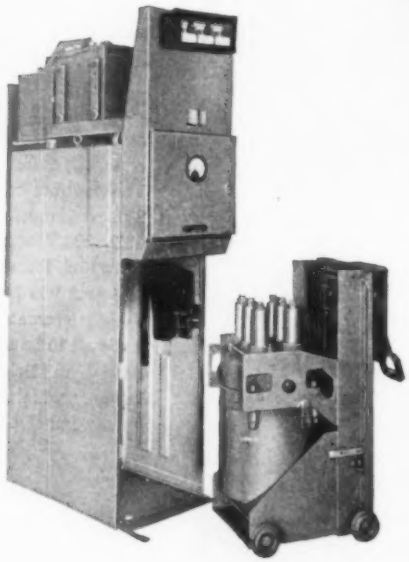
"Ferguson Pailin" have a high reputation for the manufacture of Switchgear of all ratings, from that designed for extra high voltage service within the 'Supergrid', down to medium voltage or industrial type Switchgear which may be found in service in factories and commercial buildings everywhere.



Type VSLP9 Switchgear, rated 1000-MVA breaking capacity at 33-kV.



Type K3 pedestal mounted switchgear for service up to 400-A 660-V.



Type BV Switchgear for 11-kV service up to 250-MVA breaking capacity.

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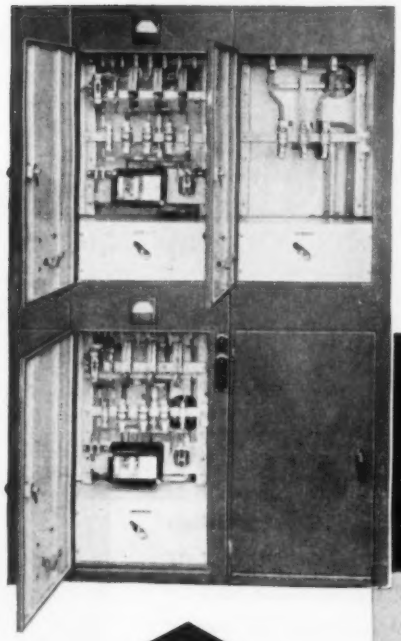
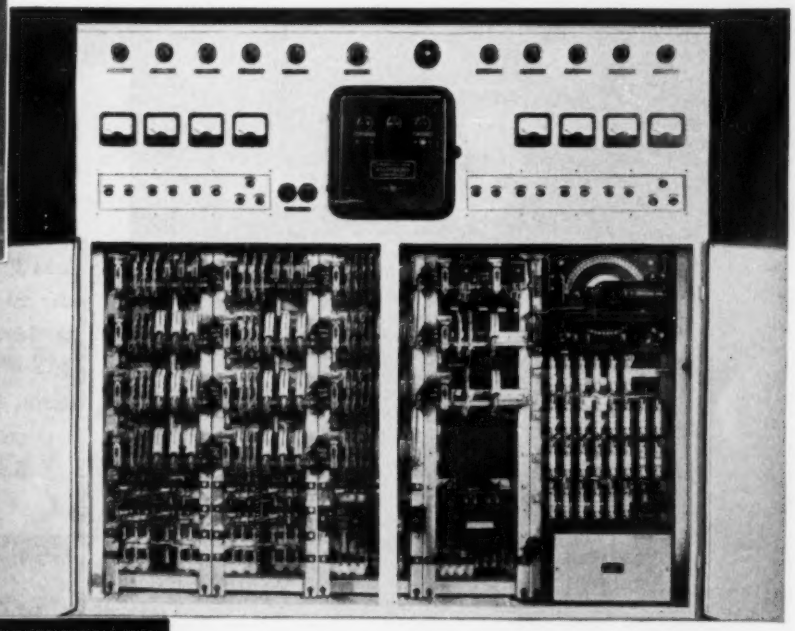
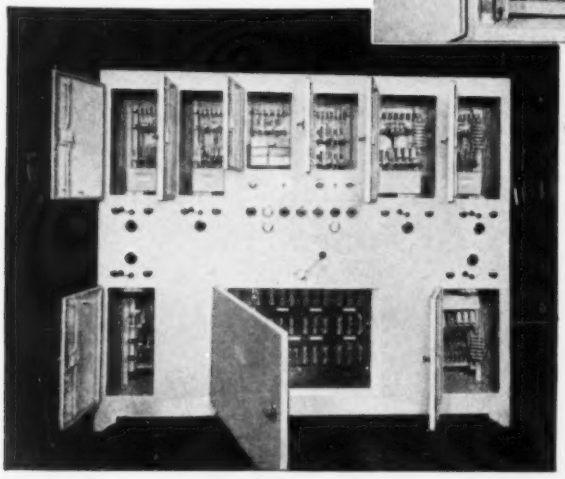


Two section, two-tier panel, one of a series supplied to a well-known paper manufacturing firm.



Multi-motor control panel with individual compartment and isolation for each motor starter, supplied to a large synthetic fibre manufacturing concern.



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All contactors are made to the famous G.W.B. standards. Among the many refinements making them pre-eminent in their field are:

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... at Hams Hall 'C'

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... another big power project for the Midlands Division of the Central Electricity Generating Board. The first of the six 60MW sets at Hams Hall 'C' was commissioned in August 1956 and all are now operating with a very high availability factor. Thus the G.E.C. keeps faith and keeps pace with Britain's power demands.

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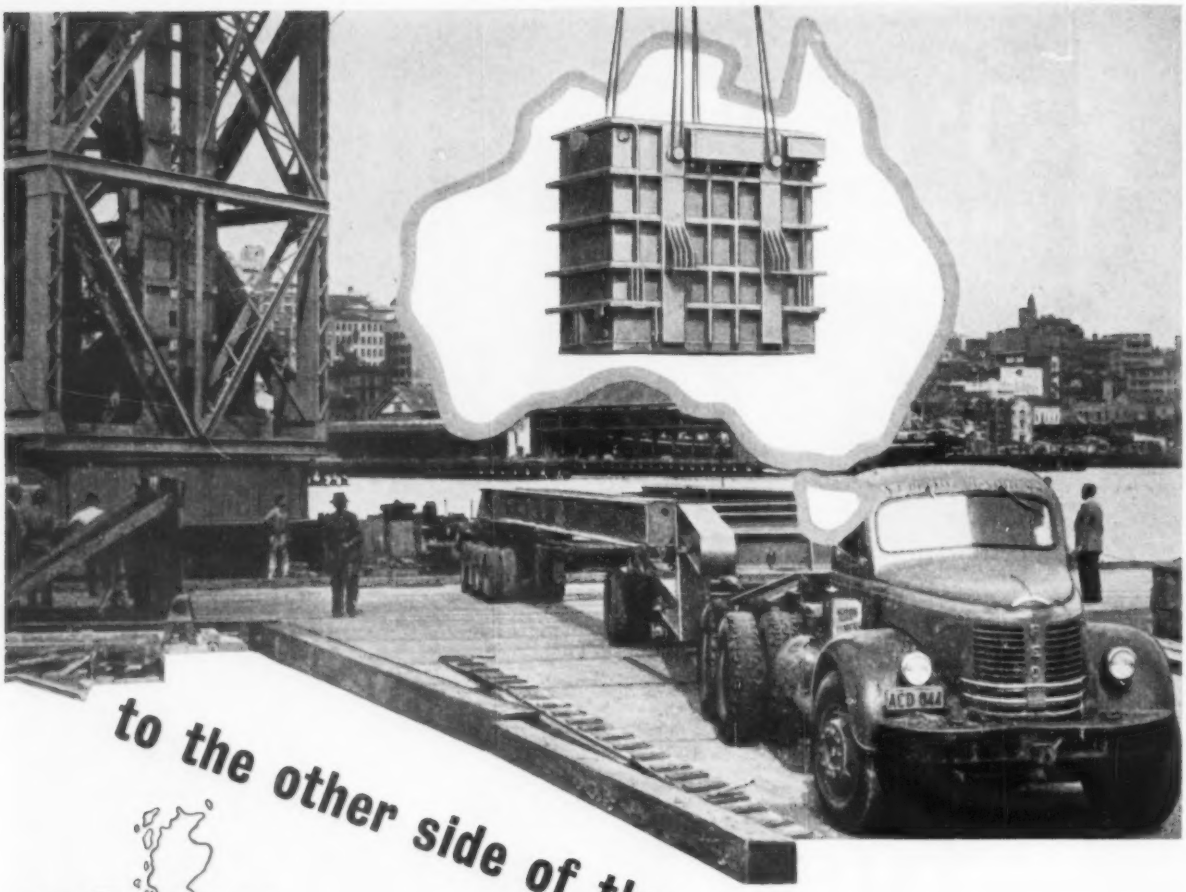

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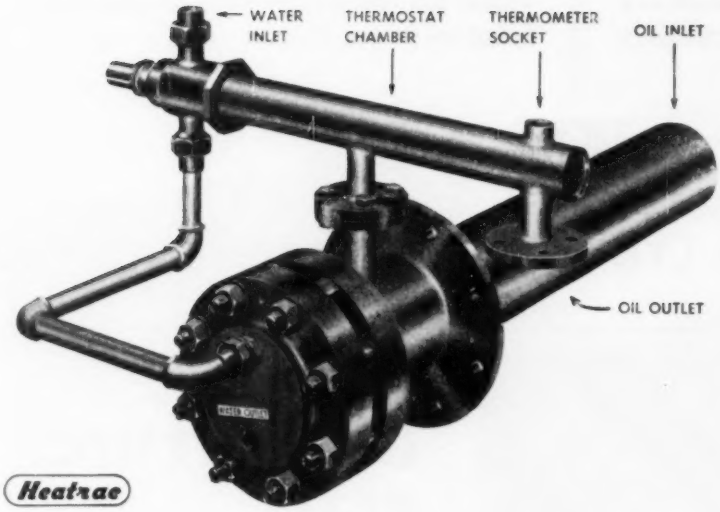

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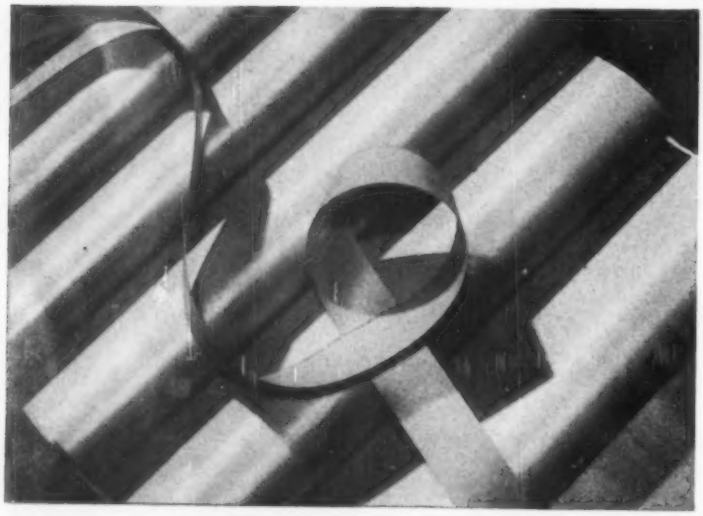

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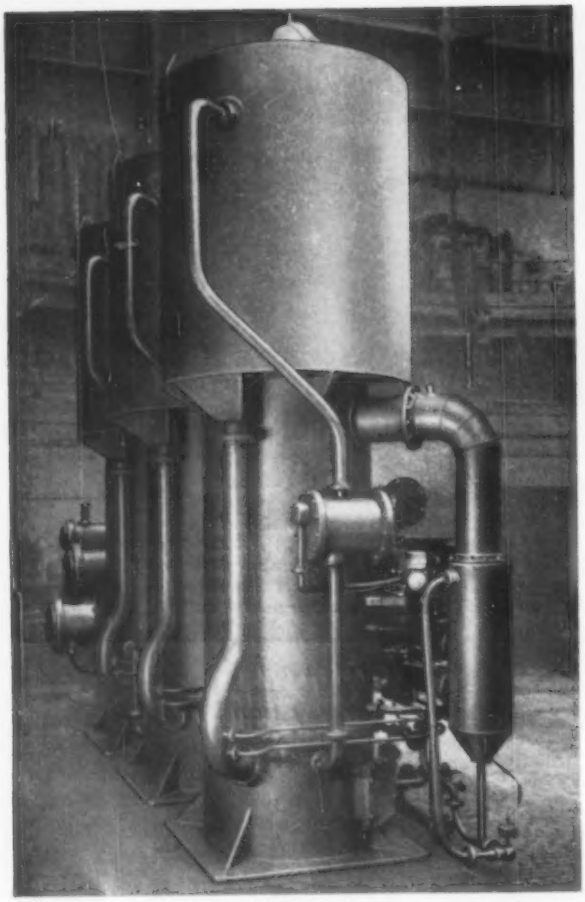

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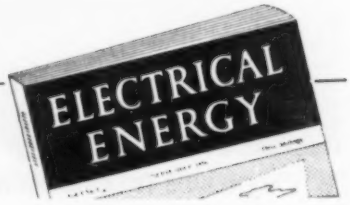

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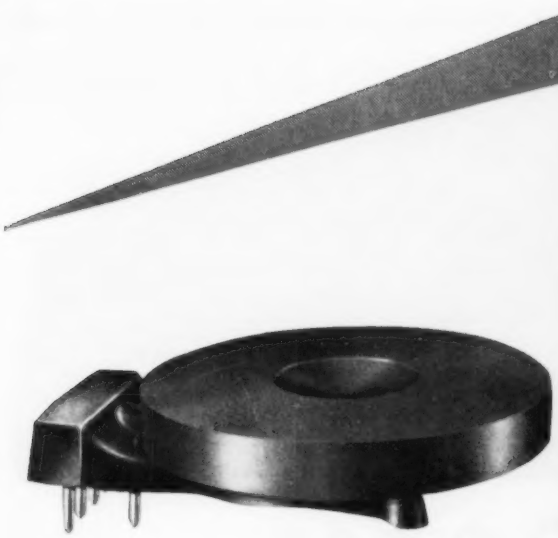

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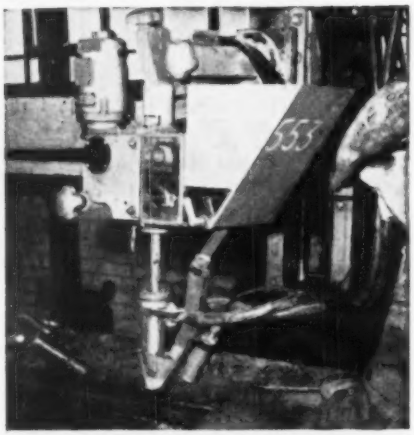

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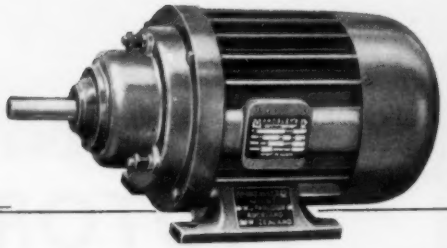

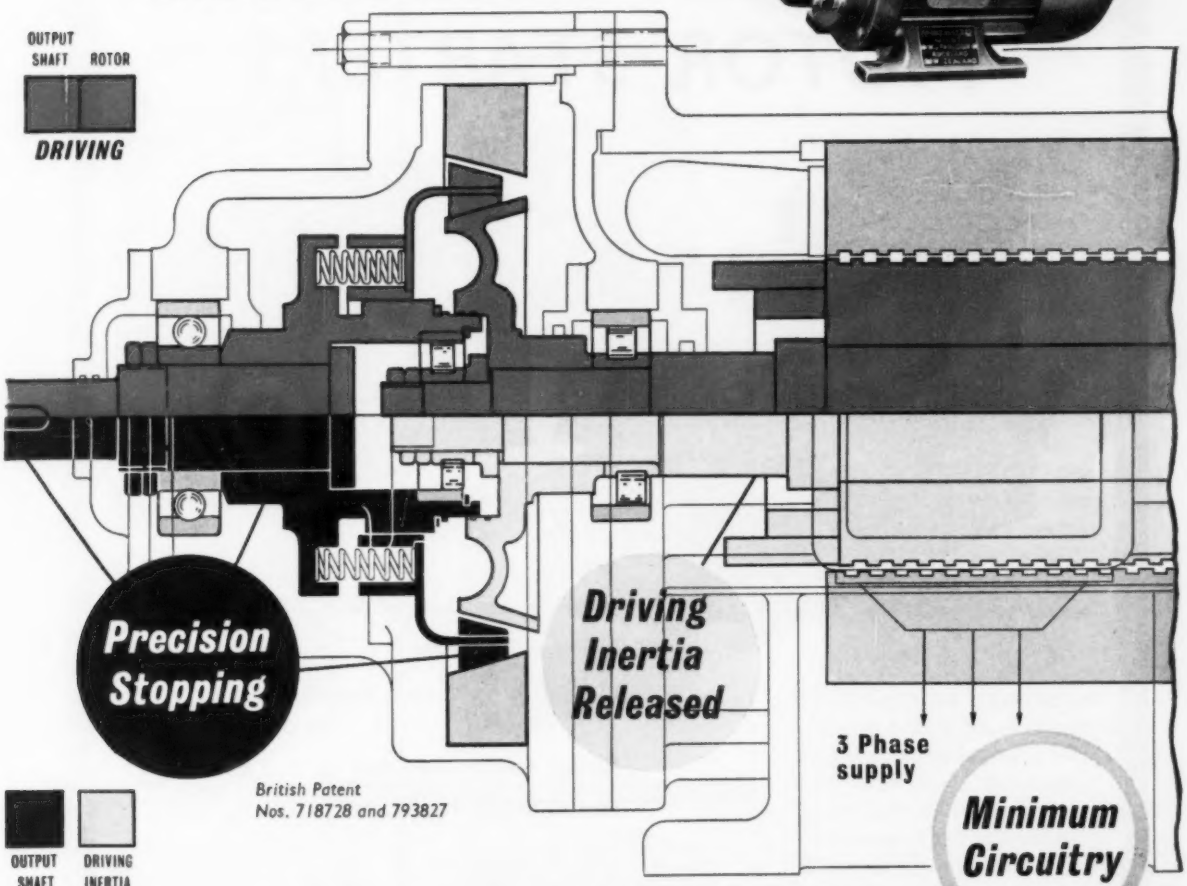

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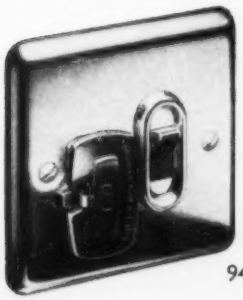
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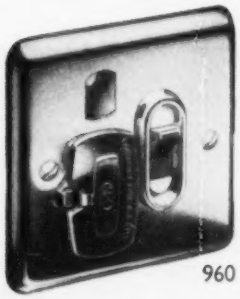
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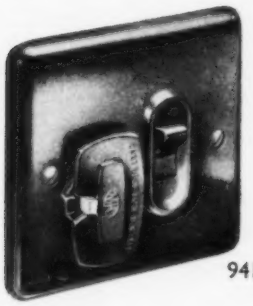
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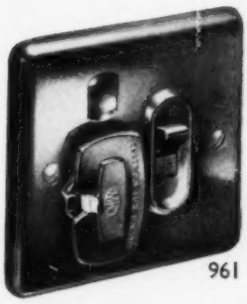
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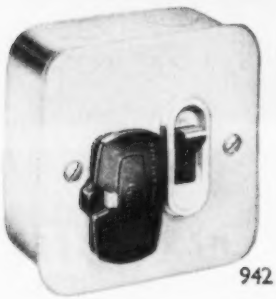
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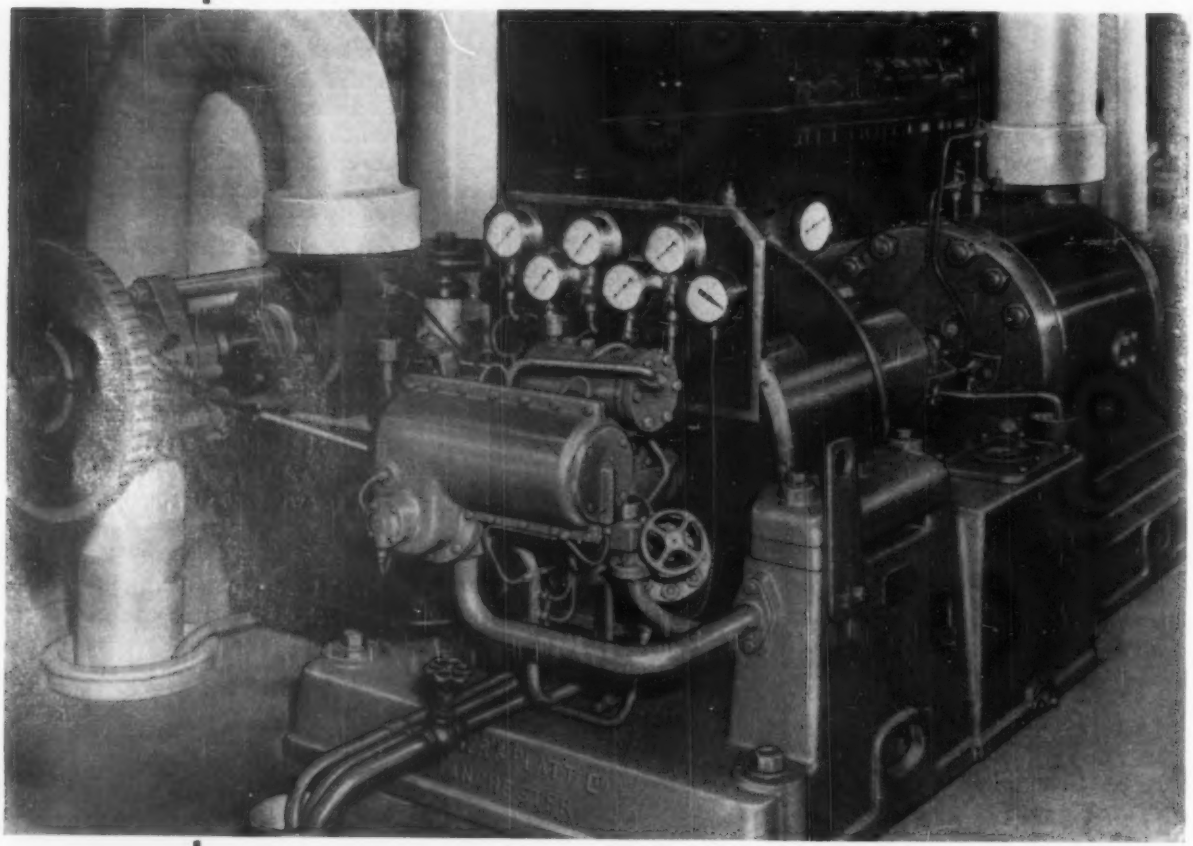

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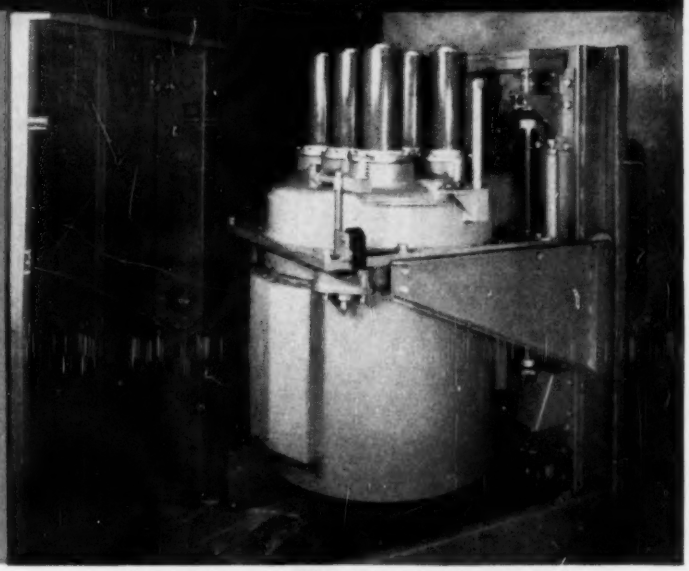

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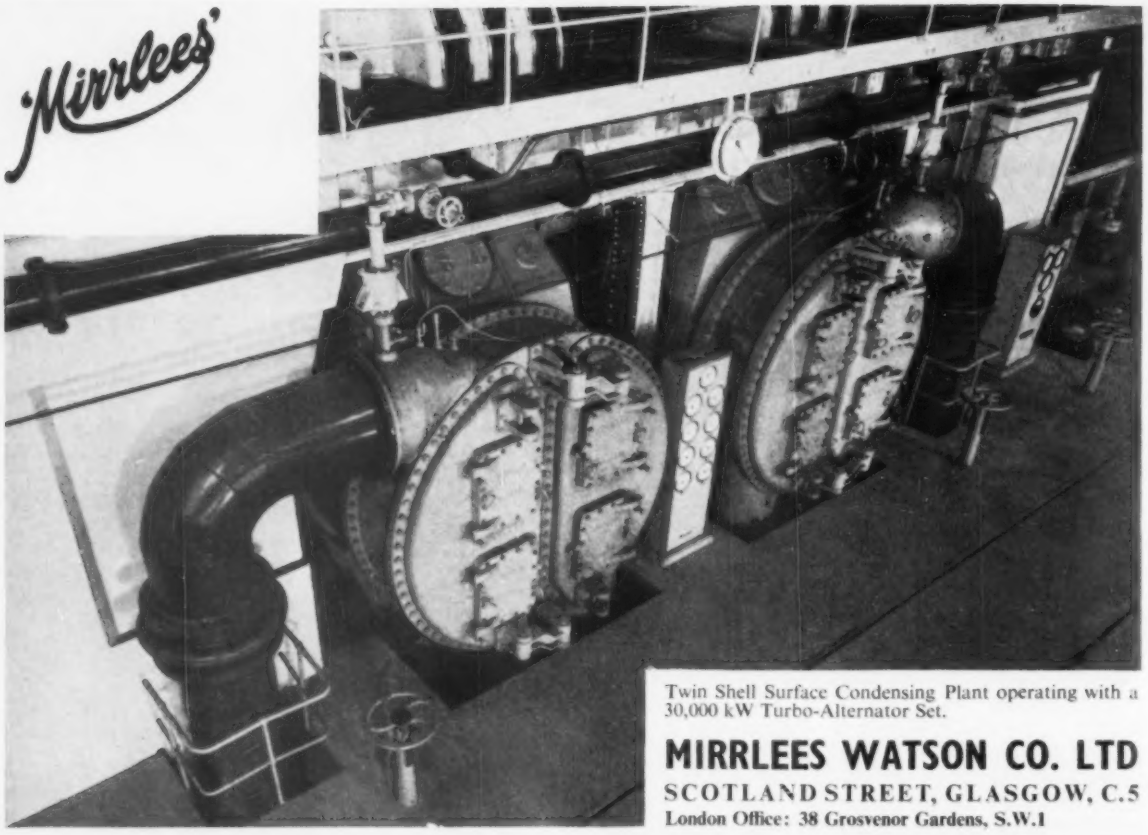

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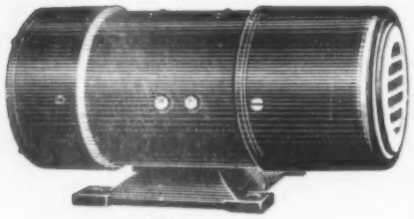

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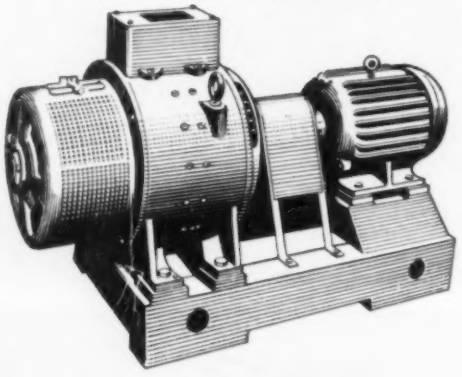

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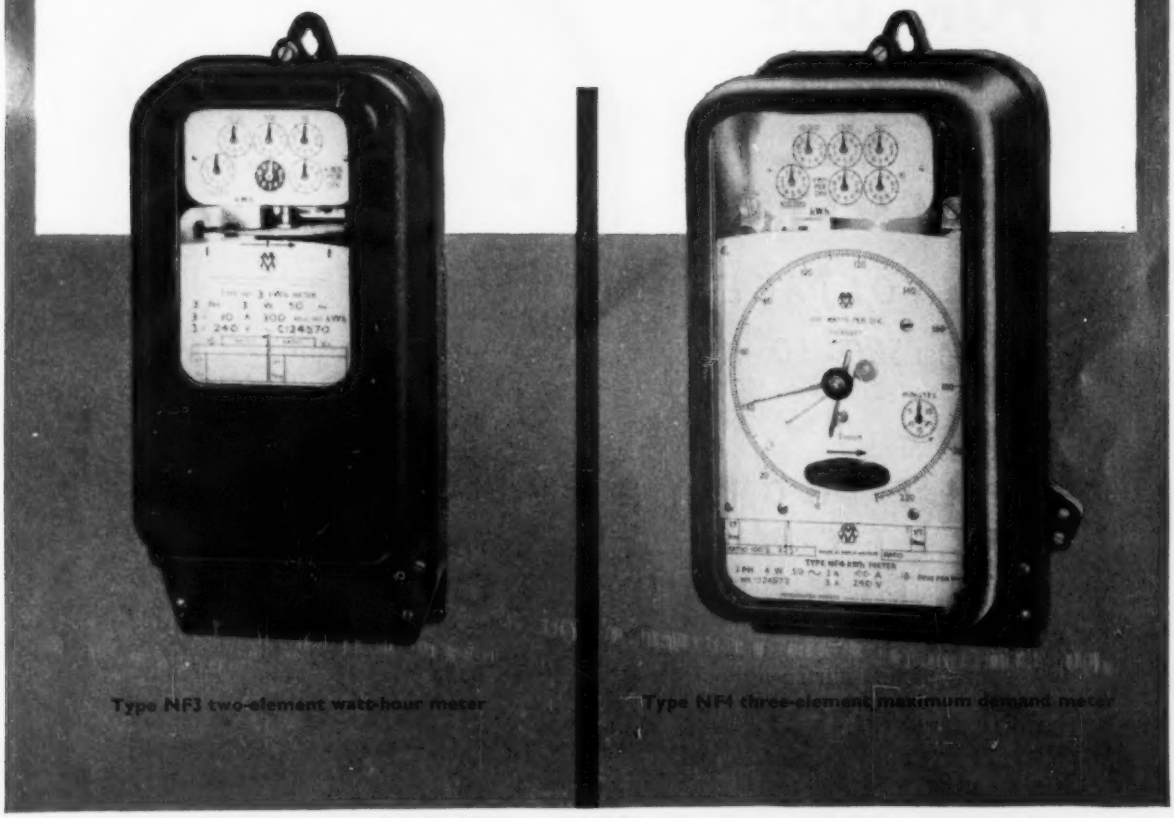

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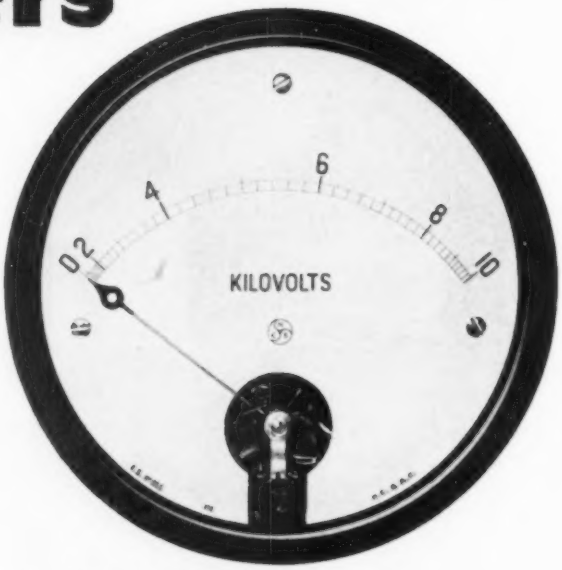

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